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RESPIRATORY CARE

A MONTHLY SCIENCE JOURNAL
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Mucosal Inflammation in Asthma (review)—R Djukanovic, WR Roche, JW Wilson, et al. Am Rev Respir Dis 1990;142:434.

Lymphocytes in the Lung: Should We Continue To Exalt Only BALT? (editorial)—JS Berman. Am J Respir Cell Mol Biol 1990; 3:101.

Is Theophylline Obsolete? (editorial)—MT Newhouse. Chest 1990;98:1. (Pertains to the Lam and Newhouse paper abstracted below.)

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Active Lung Fibrosis Up to 17 Years after Chemotherapy with Carmustine (BCNU) in Childhood—BR O'Driscoll, PS Hasleton, PM Taylor, LW Poulter, HR Gattamaneni, AA Woodcock. N Engl J Med 1990; 323:378.

Background: Carmustine (BCNU) is an anticancer drug known to produce pulmonary fibrosis as a side effect within 3 years of treatment. It is not known whether pulmonary fibrosis can appear later. Methods: To investigate the clinical range of this side effect, we studied the survivors among 31 children treated with carmustine for brain tumors between 1972 and 1976. Fourteen had died of their tumor; of the remaining 17, 6 had died of lung fibrosis—2 within 3 years of treatment and 4 from 8 to 13 years after treatment. This report focuses primarily on the 11 survivors, 8 of whom were available for detailed study 13 to 17 years (mean, 14) after treatment. Results: Of the 8 survivors studied, 6 had abnormal chest radiographs showing predominantly upper-zone fibrotic changes. These patients also had abnormal CT scans, showing a previously undescribed pattern of upper-zone fibrosis. All the survivors studied had restrictive spirometric defects (mean [± SD] vital capacity 54 ± 19% of the predicted value). Bronchoalveolar-lavage fluid contained abnormal proportions of specific macrophage subgroups. Light and electron microscopy in six patients revealed interstitial fibrosis and elastosis with damage to epithelial and endothelial cells. Four patients had symptoms (shortness of breath, cough, or both). Conclusions: Carmustine chemotherapy in childhood causes lung fibrosis that may remain asymptomatic for many years or become symptomatic at any time.

Management of Asthma and Chronic Airflow Limitation: Are Methylxanthines Obsolete?—A Lam, MT Newhouse. Chest 1990;98:44.

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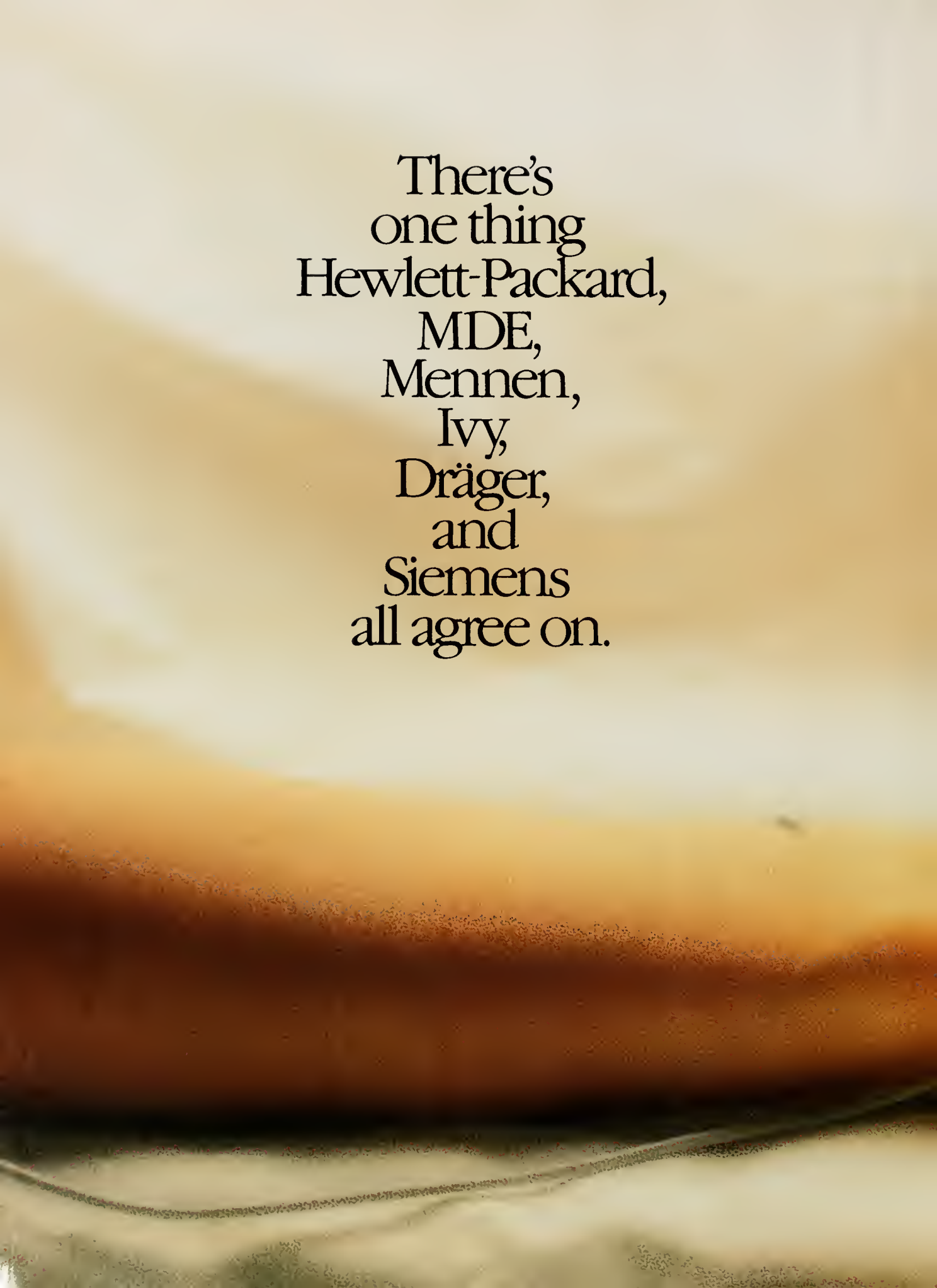
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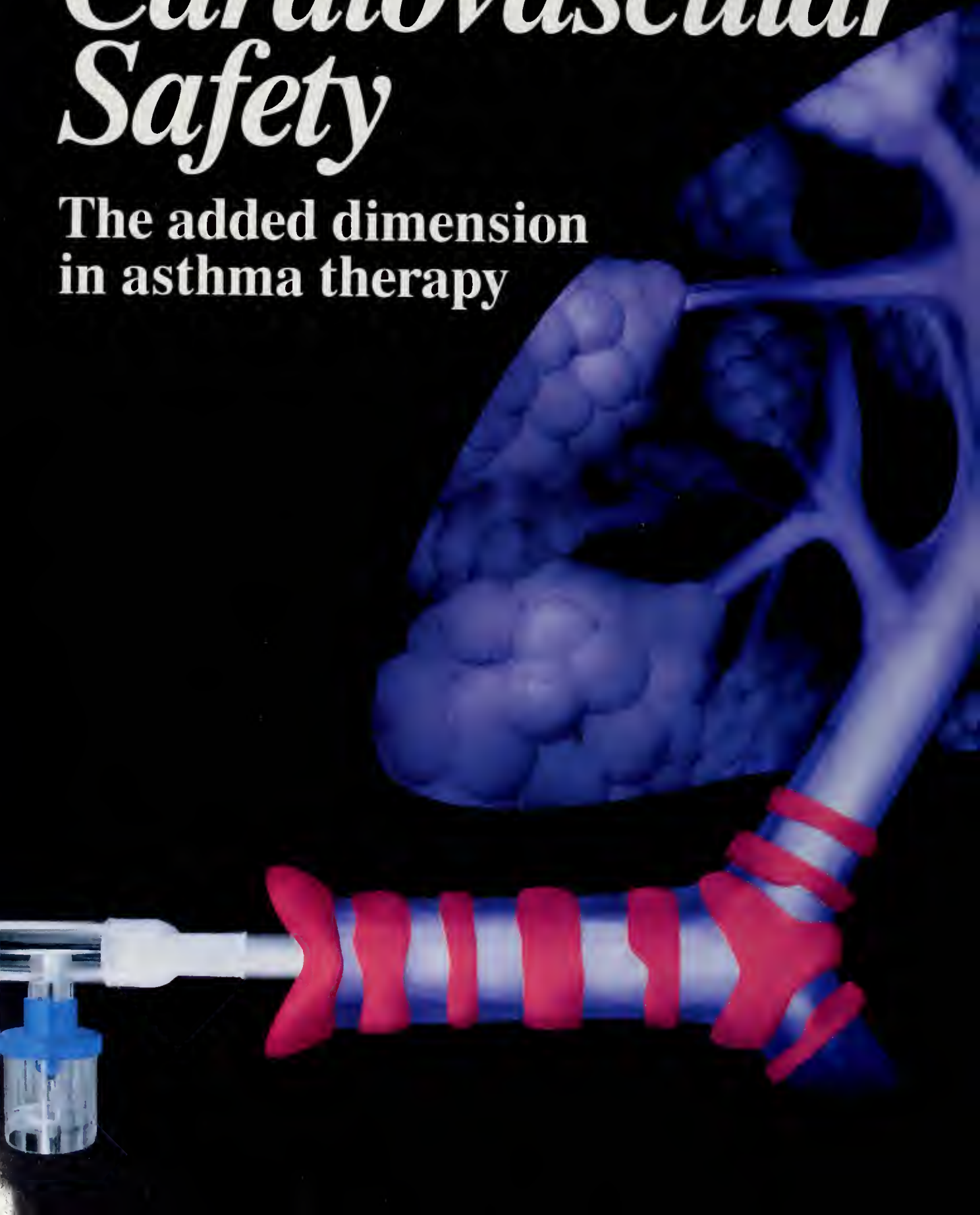

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WARNINGS Excessive use of adrenergic aerosols is potentially dangerous. Fatalities have been reported following excessive use of Alupent® (metaproterenol sulfate USP) as with other sympathomimetic inhalation preparations, and the exact cause is unknown. Cardiac arrest was noted in several cases.

Alupent, like other beta adrenergic agonists, can produce a significant cardiovascular effect in some patients, as measured by pulse rate, blood pressure, symptoms, and/or ECG changes As with other beta adrenergic aerosols, Alupent can produce paradoxical bronchospasm (which can be life-threatening). If it occurs, the preparation should be discontinued immediately and alternative therapy instituted.

Alupent should not be used more often than prescribed. Patients should be advised to contact their physician in the event that they do not respond to their usual dose of a sympathomimetic amine aerosol.

PRECAUTIONS General Extreme care must be exercised with respect to the administration of additional sympathomimetic agents.

Since metaproterenol is a sympathomimetic amine, it should be used with caution in patients with cardiovascular disorders, including ischemic heart disease, hypertension or cardiac arrhythmias, in patients with hyperthyroidism or diabetes mellitus, and in patients who are unusually responsive to sympathomimetic amines or who have convulsive disorders Significant changes in systolic and diastolic blood pressure could be expected to occur in some patients after use of any beta adrenergic bronchodilator.

Information for Patients Extreme care must be exercised with respect to the administration of additional sympathomimetic agents. A sufficient interval of time should elapse prior to administration of another sympathomimetic agent

Drug Interactions Other beta adrenergic aerosol bronchodilators should not be used concomitantly with Alupent® (metaproterenol sulfate USP) because they may have additive effects. Beta adrenergic agonists should be administered with caution to patients being treated with monoamine oxidase inhibitors or tricyclic antidepressants, since the action of beta adrenergic agonists on the vascular system may be potentiated.

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Pregnancy/Teratogenic Effects *PREGNANCY CATEGORY C* Alupent has been shown to be teratogenic and embryotoxic in rabbits when given orally in doses 620 times the human inhalation dose and 62 times the human oral dose. There are no adequate and well-controlled studies in pregnant women. Alupent should be used during pregnancy only if the potential benefit justifies the potential risk to the fetus.

Oral reproduction studies in mice, rats and rabbits showed no teratogenic or embryocidal effects at 50 mg/kg corresponding to 310 times the human inhalation dose and 31 times the human oral dose. Teratogenic effects in the rabbit included skeletal abnormalities and hydrocephalus with bone separation.

Nursing Mothers It is not known whether this drug is excreted in human milk. Because many drugs are excreted in human milk, caution should be exercised when Alupent is administered to a nursing woman.

Pediatric Use Consult package insert for age limit.

ADVERSE REACTIONS Adverse reactions are similar to those noted with other sympathomimetic agents. Adverse reactions such as tachycardia, hypertension, palpitations, nervousness, tremor, nausea and vomiting have been reported.

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HOW SUPPLIED Inhalation Aerosol Each 200 inhalations of Alupent® (metaproterenol sulfate USP) Inhalation Aerosol contains 150 mg of metaproterenol sulfate as a micronized powder in inert propellants. Each metered dose delivers through the mouthpiece 0.65 mg metaproterenol sulfate (each mL contains 15 mg). Alupent Inhalation Aerosol with Mouthpiece, net contents 14 g (10 mL). The mouthpiece is white with a clear, colorless sleeve and a blue protective cap. Alupent Inhalation Aerosol Refill, net contents 14 g (10 mL).

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References:

1. Alupent® (metaproterenol sulfate) Inhalation Aerosol full Prescribing Information.
2. Krainson JP. Metaproterenol and albuterol nebulizer solutions--a double-blind crossover study. Presented at the 46th Annual Meeting of the American College of Allergy and Immunology; November 13, 1989. Orlando, Fla
3. Habib MP, Campbell SC, Shon BY, Pinnas JL. A comparison of albuterol and metaproterenol nebulizer solutions. *Ann Allergy.* 1987;58 421-424

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Endurance-Training-Induced Cellular Adaptations in Respiratory Muscles—SK Powers, J Lawler, D Criswell, et al. J Appl Physiol 1990; 68(5):2114.

Controversy exists concerning the adaptability of mammalian respiratory muscles in response to endurance training. We examined the effects of 8 wk of progressive treadmill exercise (45 min/day 5 days/wk) on the biochemical adaptations of rat diaphragm and intercostal muscles. Female Sprague-Dawley rats were randomly assigned to a sedentary control ($n = 10$) or an exercise-training group ($n = 10$). Endurance training resulted in an enhanced oxidative capacity in the anterior costal diaphragm as evidenced by a 29% increase ($p < 0.05$) in the activity of succinate dehydrogenase (SDH) in trained animals compared with controls (4.15 ± 0.13 vs 3.21 ± 0.17 $\mu mol \cdot g^{-1} \cdot min^{-1}$). Similarly, SDH activity in the intercostal muscles was 32% greater ($p \pm 0.05$) in the trained animals than in the untrained animals (1.723 ± 0.11 vs 1.30 ± 0.06 $\mu mol \cdot g^{-1} \cdot min^{-1}$). In contrast, the crural region of the diaphragm showed no significant increase ($p > 0.05$) in oxidative capacity as a result of the training program (3.28 ± 0.12 vs 3.13 ± 0.18). Furthermore, training did not alter ($p > 0.05$) lactate dehydrogenase activity in the intercostals or in the crural or the costal diaphragm. These data demonstrate that the oxidative capacity of the costal diaphragm and the intercostal muscles can be enhanced by increasing respiratory loads via regular endurance exercise. We speculate that the lack of metabolic adaptation in the crural region of the diaphragm was not due to limited plasticity of the fibers in this area but to failure of the exercise-training program to provide the appropriate stimulus for cellular adaptation.

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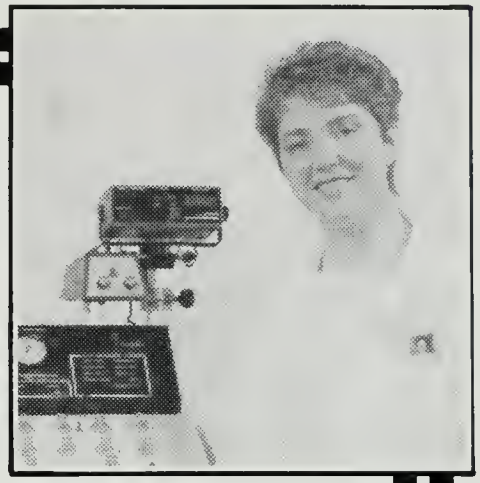

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The Effect of 100% Oxygen on the Propagation of Tracheobronchial Injury during High-Frequency and Conventional Mechanical Ventilation—TE Wiswell, SH Wiswell. AJDC 1990;144:560.

We compared the histologic alterations in the tracheae and bronchi of 30 premature baboons that were ventilated with either 100% or prn (as needed) oxygen (the fraction of inspired oxygen necessary to maintain the P_{aO_2} between 50 and 80 torr). The baboons were treated with either conventional positive-pressure ventilation (7 were treated with 100%; 7 prn) or high-frequency oscillatory ventilation (8 were treated with 100%; 8 prn). We used a semiquantitative scoring system to grade tissue changes in the trachea, carina, and main-stem bronchi. The fraction of inspired oxygen for all prn animals fell to a plateau of approximately 0.28 after 36 h, where it remained for the duration of the study. The 15 100%-baboons were ventilated for a mean of 139 h, while the 15 prn-baboons were ventilated for a mean of 151 h. The findings in all conventional and oscillator-ventilated animals were similar and characterized by squamous metaplasia, cilia loss, and goblet cell loss. For both methods of ventilation, there were no differences in the injury scores between 100% and prn oxygen-treated animals. We concluded that there were no additional tracheobronchial histologic changes with 100% oxygen compared with prn oxygen.

Hydration during the First Days of Life and the Risk of Bronchopulmonary Dysplasia in Low-Birthweight Infants—LJ Van Marter, A Leviton, EN Allred, M Pagano, KCK Kuban. J Pediatr 1990;116:942.

We conducted a case-control study of antecedents of bronchopulmonary dysplasia (BPD) in 223 infants enrolled in a prospective, randomized clinical trial of phenobarbital prophylaxis for intracranial hemorrhage. The trial took place at three Boston neonatal intensive care units between June 1981 and April 1984. The 76 babies with BPD had radiographic evidence of the condition and required oxygen therapy for 28 days or more. All 147 control babies survived until Day 28 of life without meeting either of these criteria for BPD. Compared with control infants, those with BPD received greater quantities of total, crystalloid, and colloid fluids per kilogram per day in the first 4 days of life. In addition, infants with BPD generally had a net weight gain in the first 4 days of life in contrast to the normal pattern of weight loss seen in control infants. Finally, the infants with BPD were more likely to be given a clinical diagnosis of patent ductus arteriosus and to have received furosemide on Days 3 and 4 of life. From these observations we infer that early postnatal phenomena such as excessive fluid therapy may be important in the pathogenesis of BPD.

The Ventilatory Recruitment Threshold for Carbon Dioxide—GC Prechter, SB Nelson, RD Hubmayr. Am Rev Respir Dis 1990;141:758.

We report our initial experience with a technique with which the chemoresponsiveness of the respiratory controller can be characterized in terms of an inspiratory on-switch threshold to CO_2. After suppression of phasic respiratory muscle activity by mechanical ventilation, a CO_2 recruitment threshold ($P_{CO_2}RT$) was defined as the lowest alveolar CO_2 tension at which CO_2 supplementation to inspired gas caused a reappearance of inspiratory efforts. Because $P_{CO_2}RT$ can be determined in the absence of a mechanical load on the ventilatory pump, respiratory system mechanics and inspiratory muscle function should not influence the measurement itself. Thus, this technique may be helpful to study ventilatory requirements and load responses in critically ill patients with respiratory failure. We have shown that inspiratory muscle recruitment can be equally well-inferred from changes in the airway pressure and flow tracings during mechanical ventilation, from the pattern of chest-wall displacement, and from the integrated diaphragm electromyogram. Within a subject, $P_{CO_2}RT$ is a reproducible measurement that is not influenced by ventilator settings and end-expiratory lung volume, provided that phasic respiratory muscle has been suppressed prior to CO_2 supplementation. Details of the methodology, the likely determinants of $P_{CO_2}RT$, and the clinical utility of this technique are discussed.

Investigator/ Clinician
MICU Respiratory Research Coordinator

Principal responsibilities involve the design and implementation of clinical research protocols developed by respiratory care and ICU physicians. Qualifications are comprehensive experience in pediatric critical respiratory care with attendant educational skills. Knowledge of computers, statistics, and research design are desirable. Requires broad and indepth knowledge of complex life support systems.

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Ribavirin and Pentamidine Aerosols: Caregiver Beware!

Aerosol therapy has been a cornerstone of respiratory care since the profession began in the 1940s,[1-4] and pharmacologic agents from antibiotics[1,3] to sympathomimetics[4] have been delivered to patients via aerosol by respiratory care practitioners. As a consequence of the familiarity resulting from this history, respiratory care practitioners tend to be cavalier about the administration of any aerosolized pharmacologic agent.

Two recent additions to the long list of pharmacologic agents administered by aerosol are ribavirin (Virazole) and pentamidine isethionate. Ribavirin has been demonstrated to be effective in the management of various respiratory virus infections,[5-7] especially respiratory syncytial virus (RSV) in infants,[8-10] and it is considered by some to be life-saving in the presence of the often lethal combination of RSV and cardiac disease in small infants.[11] Pentamidine, on the other hand, has been demonstrated to be effective in both the prevention and treatment of *Pneumocystis carinii* pneumonia in the immunodeficient host.[12-17]

The question of the effectiveness of these agents has been answered at least in part, but what of the question of the safety of the caregiver administering these agents? Does the caregiver administering the aerosol expose himself to a health hazard? Ribavirin is classified as teratogenic in small mammals. A single oral dose of 2.5 mg/kg produced teratogenicity in hamsters,[18] as did a single oral dose of 10 mg/kg in the rat.[19,20] These animals demonstrated malformation of the skull, gastrointestinal tract, eye, jaw, palate, and skeleton, and the survival of offspring was reduced. Doses as low as 1 mg/kg resulted in embryo death in rabbits.[21] Similar findings were noted in ferrets.[22] However, no teratogenic effects were noted in baboons receiving 120 mg/kg administered in 4-day pulses during critical periods of gestation ranging from gestation days 20-39.[21] ICN Pharmaceuticals Inc states that the drug is contraindicated in women and girls who are or may become pregnant during exposure to the drug.[23] Ribavirin is not completely cleared from human blood even 4 weeks after administration.[23]

Although not as well documented, similar concerns exist for pentamidine. Unfortunately, little or no information is available on the potential effects of pentamidine on the fetus.[24] Pentamidine inhibits protein and nucleic acid synthesis in vitro and may be a folic acid antagonist, but its exact mechanism of action is unclear.[25] However, folic acid antagonists have been associated with increased incidence of spontaneous abortion, death, multiple congenital malformation, and growth retardation.[26] Possibly more important are the potential pulmonary effects of pentamidine on caregivers. A letter published in the *American Review of Respiratory Diseases* reported a decreased diffusing capacity in a 47-year-old respiratory therapist who had administered pentamidine over a 14-month period.[27] A recent memorandum from the California Department of Industrial Relations documented acute episodes of shortness of breath, cough and chest tightness, burning sensations in the eyes, nose, and throat, sinus irritation, sneezing, nausea, light-headedness, and headache, in 10 respiratory therapists administering pentamidine without protection from exposure to the drug.[28]

A second problem associated with the administration of pentamidine is possible transmission of respiratory pathogens via droplet nuclei generated by the coughing of patients receiving aerosolized pentamidine.[29] Because pentamidine is most commonly administered to immunosuppressed patients with AIDS, the possible transmission of *Mycobacterium tuberculosis* must be considered. Recent reports suggest a high association between active *M tuberculosis* and HIV infection.[30,31]

It would thus seem prudent for all of us to alter our cavalier attitude toward the delivery of aerosolized medication and to look for methods to protect ourselves from exposure to potentially harmful agents. In this issue of RESPIRATORY CARE, Charney et al[32] report the effectiveness of a double tent setup for

limiting ribavirin environmental levels. With their system, the time-weighted-average exposure levels of ribavirin were below the level considered hazardous by both the California[33] and Massachusetts[34] Departments of Environmental Health. I congratulate these researchers on their efforts, but as they indicate, these results, although promising, are preliminary and require substantiation. Before the approach presented is universally adopted, exposure levels during the actual treatment of patients must be measured and confirmed by other researchers because the scavenging and analysis of ribavirin is difficult and prone to inaccuracies.

At the present time, caregivers should adhere strictly to guidelines for the administration of ribavirin and pentamidine.[28,33-35] First, pregnant practitioners and both male and female workers who are trying to conceive should avoid exposure to these drugs.[28,34] Second, both drugs should be administered only in isolation rooms with a separate air circulating system equipped with HEPA filters.[28,34,35] The pressure in treatment rooms should be less than in surrounding rooms (ie, 'negative' pressure) to prevent both the drug and droplet nuclei from leaving the room. Fresh air ventilation should be provided to ensure at least 20 room-volume changes per hour during pentamidine administration.[35] In addition, ultraviolet radiation greatly reduces the risk of *M tuberculosis* transmission. Specific recommendations regarding ribavirin have not been promulgated; however, the more frequent the air-volume change, the lower the drug concentration. Third, with ribavirin an OSHA-approved respirator with a protection factor of at least 10[32] should be worn. Prudence dictates barrier protection (masks, gloves, goggles, and gown) until safe environmental drug concentrations have been demonstrated. Fourth, common sense dictates that the time of exposure to these drugs should be as short as possible. When either of these drugs is administered via a mechanical ventilator, concern regarding environmental exposure is reduced, provided appropriate filters are placed in the expiratory limb.[28] In our institution, we take the additional steps of assuring that a proper seal is obtained at the airway and that the nebulizer is turned off and left in the ventilator circuit for 2-5 minutes before removal.

To many, these guidelines may seem to be an unnecessary overreaction. However, I believe that too few data are available to justify a less conservative approach, when the well-being of caregivers and future offspring is at stake. Further, we must all continue to explore possible approaches to the safe administration of all potentially harmful aerosols.

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Treatment Time and Patient Tolerance for Pentamidine Delivery by Respirgard II and AeroTech II

Colleen Vinciguerra RN BS and Gerald Smaldone MD PhD

BACKGROUND: The U.S. Public Health Service has recommended aerosolized pentamidine for prophylaxis for *Pneumocystis carinii* pneumonia in HIV-infected persons. We compared the Respirgard II and the AeroTech II nebulizer systems to determine whether nebulizer output differences would affect patient tolerance and treatment time. METHOD: Equivalent monthly doses were approximated based on results from previous nebulizer studies—300 mg for the Respirgard II and 150 mg for the AeroTech II. Twenty-four patients received two monthly randomized treatments, one with each nebulizer. Treatments were administered in our outpatient clinic. Patient tolerance was evaluated by use of a cough scale. RESULTS: Treatment time for the Respirgard II ranged from 15 to 60 min, with a mean (SD) of 29.1 (9.6). For the AeroTech II, treatment time was significantly shorter ($p < 0.0001$) with a narrower range (10 to 15 min, with a mean [SD] of 13.0 [1.7]). Patients were more likely to cough during treatment with the AeroTech II ($p = 0.014$); however, this did not have an impact on patient tolerance. Twenty one of the twenty-four patients completed treatment with both nebulizers without major adverse reactions. CONCLUSION: We conclude that pentamidine aerosol from either nebulizer can be tolerated by patients for prophylaxis and that nebulizer selection may affect the cost and time of therapy. (Respir Care 1990;35:1037-1041.)

Introduction

Pneumocystis carinii pneumonia (PCP) remains the most common presenting manifestation of the acquired immunodeficiency syndrome (AIDS) and is a leading cause of morbidity and mortality in those infected with the human immunodeficiency virus (HIV).[1] HIV-infected persons who have already had an episode of PCP and those with T-helper lymphocyte (CD4+) counts of less than 200/mm^3 are considered to be at risk for PCP.[2]

The U.S. Public Health Service has recommended two medication regimens for prophylaxis against PCP in HIV-infected individuals: trimethoprim-sulfamethoxazole given orally and pentamidine given as an aerosol. Prophylaxis is termed primary if the patient has never had an episode of PCP and secondary if the patient has had at least one episode of the disease.[1] The use of aerosolized pentamidine has advanced the understanding and prevention of PCP. Its ability to achieve high alveolar concentrations and low serum levels while being well-tolerated by patients has led to widespread application.[3] Aerosolized pentamidine, when used as prophylaxis, reduces PCP-relapse rates in persons with AIDS by 50% and delays PCP recurrence by 6 months.[4]

The recent FDA approval (June 1989) of aerosolized pentamidine was based on a single controlled clinical study that showed that patients who received 300 mg of aerosolized pentamidine every 4 wk experienced fewer episodes of PCP than those receiving 30 mg every 2 wk or 150 mg every 2 wk.[2] All groups used the same nebulizer (the Respirgard II Nebulizer System, Marquest Medical, Englewood CO).

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Other nebulizer systems for delivering aerosolized pentamidine have been investigated. At our institution, we have clinical and laboratory experience utilizing both the Respirgard II and the AeroTech II (Cadema, Middletown NY) nebulizer systems. Controlled studies measuring particle size, distribution, and output have been performed comparing the two systems. They have been found to have similar particle sizes as measured by mass median aerodynamic diameter (0.76 μ for the Respirgard II and 1.0 μ for the AeroTech II).[5] However, when nebulization continued to dryness, the mean output from the AeroTech II was 2.5 times greater than the mean output of the Respirgard II.[6] Also, the AeroTech II delivered its full dose in a significantly shorter period of time (12-15 min vs 30-40 min).[5,6] If these findings apply to clinical use, choice of nebulizer could have important economic implications. The amount of drug required for a given treatment and the time allocation for these treatments would be affected.

However, it has been uncertain whether laboratory tests of nebulizer function would predict clinical experience and patient tolerance. We therefore designed a short-term controlled clinical study to compare the two nebulizer systems. The purpose of this study was to determine whether nebulizer output differences, using approximately equivalent monthly doses, would have an effect on treatment time and, more importantly, on patient tolerance.

Materials and Methods

Nebulizers

The Respirgard II delivery system contains one-way valves that control a drug reservoir and regulate the direction of airflow. The valves allow entrainment of room air and act as a baffle to decrease particle size. Expired air and drug are exhaled into a filter to prevent environmental contamination (Fig. 1). The AeroTech II differs in that it has internal baffles in the nebulizer that allow recycling of the drug (Fig. 2).[7]

The recommended dose for monthly prophylaxis with the Respirgard II consists of pentamidine isethionate 300 mg dissolved in 6 mL of sterile water nebulized at 6 L/min until the nebulizer reservoir is dry.[1] The approximate equivalent monthly dose for the AeroTech II, based on previous studies,[5,6] is 150 mg of pentamidine given in 4 mL of sterile water at a nebulizer flow of 10 L/min until dry.

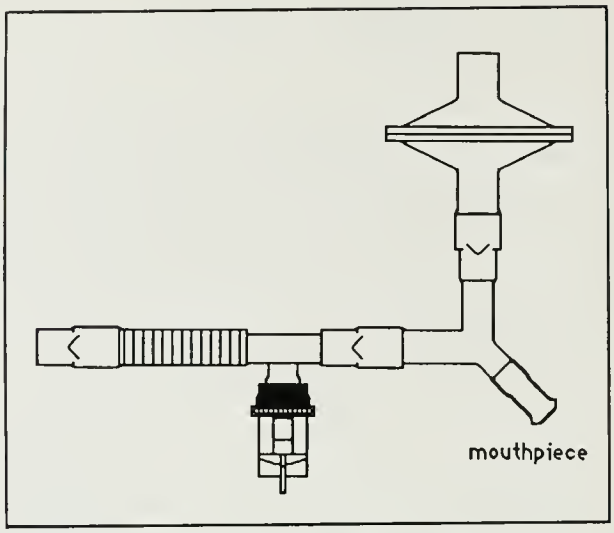

Fig. 1. The Respirgard II jet nebulizer system. Three one-way valves control airflow and regulate particle size. The exhalation filter prevents environmental contamination.

Experimental Design

This was a prospective, randomized, short-term study conducted at the AIDS Treatment Center, University Hospital, Stony Brook NY. Patients were asked to participate if they were attending the clinic

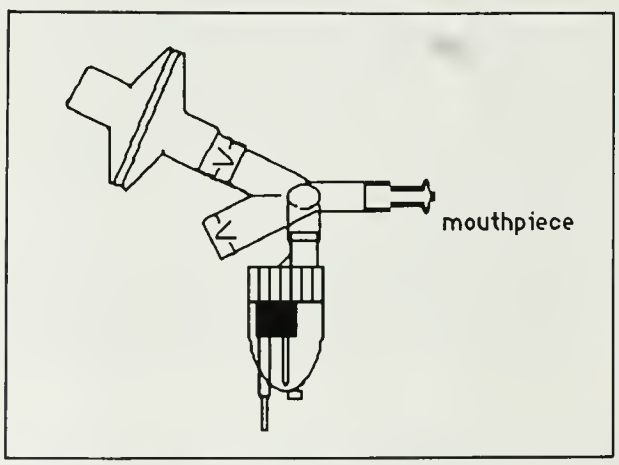

Fig. 2. The AeroTech II jet nebulizer system. This system utilizes two one-way valves to control airflow and internal baffles to regulate particle size. The exhalation filter prevents environmental contamination.

for aerosolized pentamidine prophylaxis on a monthly basis and were capable of signing informed consent. All treatments were given by one of two registered nurses who regularly give aerosolized pentamidine treatments. A total of 24 patients agreed to participate in the study.

Each patient was asked to take two treatments one month apart during the study period—one with the Respirgard II and one with the AeroTech II. Nebulizers were randomly assigned at the first visit, and the other nebulizer was used during the second visit, regardless of the patient's treatment history. Baseline information obtained on each patient included age, sex, PCP history, other pulmonary history, current medications, and aerosolized pentamidine history.

Each patient was carefully instructed on proper nebulizer technique prior to each treatment. Patients were told to breathe at their normal rate, via the mouth, while sitting up in a chair. Albuterol (Proventil, Schering Corp, Kenilworth NJ) was given via metered dose inhaler to all patients prior to each treatment because some patients were using bronchodilators prior to the study. Airflow from a piped source was regulated with an adjustable flowmeter.

During each treatment, patients were observed for signs of distress or poor technique. Patients were instructed to raise their hand if they required a break in therapy. When a temporary break occurred, the air source was turned off. Treatment time was based on actual nebulizer use only and did not include break periods.

Patient tolerance was rated by the number of coughing bouts during each treatment. A cough scale was established giving a score of 0 if no cough occurred, 1 if one to two bouts of cough occurred, 2 if three to four bouts of cough occurred, and 3 if more than four bouts of cough occurred.

Statistical significance of differences between the two nebulizers with regard to treatment time was analyzed by paired *t* test. Differences in cough were assessed by the Wilcoxon signed rank test.

Results

The patient sample consisted of 19 men (79%) and 5 women (21%). The age range was 25-51 years (mean age 36 y). Seventeen patients (71%) were active smokers and 7 (29%) were nonsmokers. Nineteen patients (79%) were receiving aerosolized pentamidine as primary prophylaxis and 5 (21%) as secondary prophylaxis. Prophylaxis history ranged from 0 to 18 months. Twelve patients (50%) were taking treatment for the first or second time. Twelve patients (50%) had a history of other respiratory disease: non-PCP pneumonia (9), asthma (2), and tuberculosis (2). Of the 24 patients, 21 were able to complete both treatments without major adverse reactions. Of the remaining three patients, therapy was complicated by wheezing with both nebulizers (Patient 13), severe coughing with both nebulizers (Patient 21), and extreme restlessness during treatment with the Respirgard II (Patient 5). The patient who developed severe wheezing (Patient 13) had a history of asthma.

Treatment times are summarized in Figure 3. Time could not be calculated for Patient 5 with the Respirgard II, Patient 11 with the AeroTech II, and Patients 13 and 21 with both nebulizers. For the Respirgard II, treatment time ranged from 15 to 60 min with a mean (SD) of 29.1 (9.6). For the AeroTech II, time ranged from 10 to 15 min with a mean

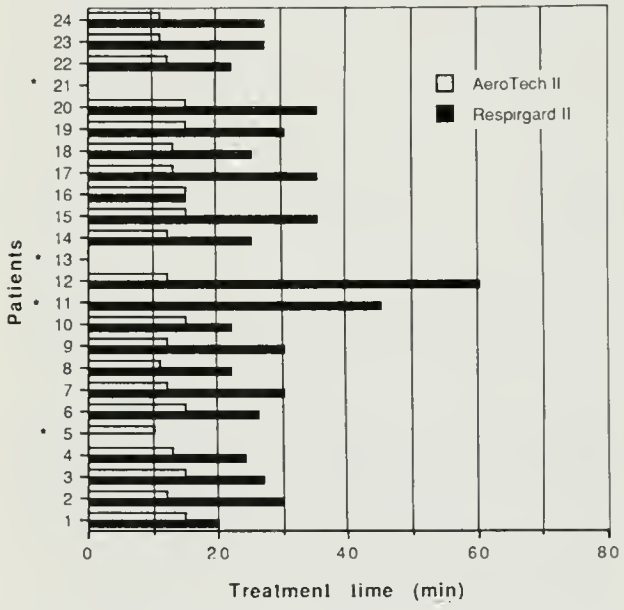

Fig. 3. Comparison of nebulizer treatment times for each patient. Solid bars represent the Respirgard II nebulizer system; open bars represent the AeroTech II. An asterisk is present if the treatment time could not be calculated (eg, severe coughing, wheezing, restlessness, or technical error).

(SD) of 13.0 (1.7). As shown in Figure 3, treatment time with the Respirgard II was not only longer ($p < 0.0001$) but was more variable between patients than with the AeroTech II.

The incidence of cough for individual patients is detailed in Figure 4, and the cough frequency

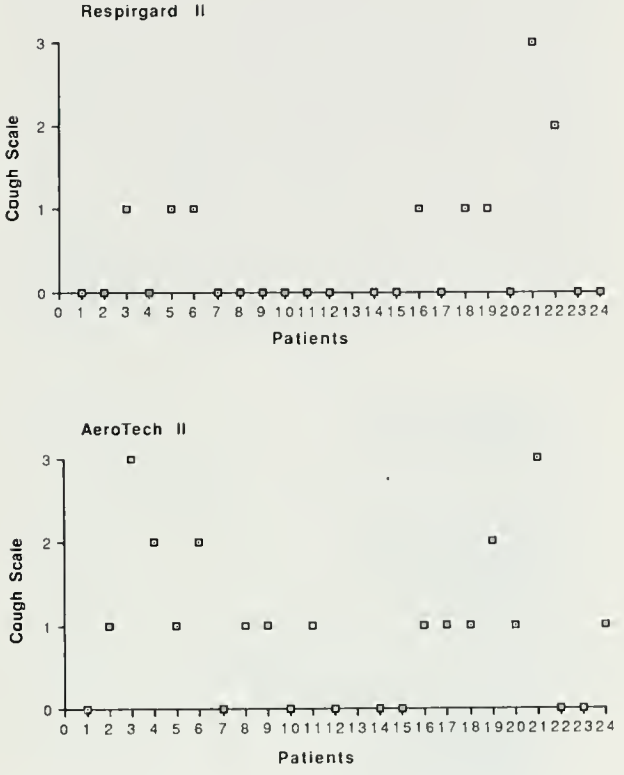

Fig. 4. Incidence of cough in patients utilizing the Respirgard II (upper panel) and AeroTech II (lower panel) nebulizers. Cough Scale 0 = no coughing; Cough Scale 1 = one to two bouts of coughing; Cough Scale 2 = three to four bouts of coughing; Cough Scale 3 = more than four bouts of coughing. Patient 13 was excluded due to severe wheezing.

categories are listed and averaged in Table 1. (Patient 13 was excluded due to severe wheezing.) In summary, the overall incidence of cough with the AeroTech II was significantly greater ($p = 0.014$). Twenty-one patients (91%) using the Respirgard II experienced little or no cough (Cough Scale 0 and 1) compared to 18 (78%) with the AeroTech II. On the other hand, two patients (9%) experienced moderate to severe cough (Cough Scale 2 and 3) with the Respirgard II as compared to 5 (22%) with the AeroTech II.

No statistically significant relationships between patient demographics and treatment time and cough were observed; however, the two patients who scored a Cough Scale 3 (more than 4 bouts) were both smokers.

Discussion

This study was designed to be a short-term comparison of the Respirgard II and the AeroTech II jet nebulizers, both used at our institution, for the prophylactic administration of aerosolized pentamidine. Specifically, we evaluated treatment time and patient tolerance with the two systems.

Prior to the FDA approval for aerosolized pentamidine, nebulizer treatment regimens and dosages for prophylaxis had varied markedly. Regulatory approval was based on one study that had demonstrated clinical effectiveness using the Respirgard II nebulizer with 300 mg on a monthly basis.[2] This established the first clinical standard for aerosolized pentamidine prophylaxis; however, patients are currently using other nebulizer systems for which standards are lacking.

Clinical effectiveness with the AeroTech II has recently been evaluated using a bimonthly treatment regimen (60 mg every 2 wk).[8] Preliminary results suggest that successful prophylaxis can be achieved with this nebulizer. However, because of the increased output of the AeroTech II, it was thought that the greater inhaled concentration of drug per breath with this nebulizer might affect patient tolerance (ie, might produce increased cough) if given on a monthly basis (ie, doubling the usual single dose).

Table 1. Incidence of Cough Experienced by 23 Patients with Use of the Respirgard II and AeroTech II Nebulizers*

Cough Scale	Respirgard II	AeroTech II
Cough Scale 0 (no cough)	15 (65%)	8 (35%)
Cough Scale 1 (1-2 bouts)	6 (26%)	10 (43%)
Cough Scale 2 (3-4 bouts)	1 (4%)	3 (13%)
Cough Scale 3 (> 4 bouts)	1 (4%)	2 (9%)

*The twenty-fourth patient, Patient 13, was excluded because of severe wheezing.

Cough has been reported as the most frequently occurring adverse effect experienced with aerosolized pentamidine.[9] As many as 69% of patients using the Respirgard II experienced cough at some point during one long-term study.[2] For this reason, we used cough as an indicator for comparison of patient tolerance with the two nebulizer systems. In our study, a total of 8 patients (35%) experienced some degree of cough with the Respirgard II, whereas a total of 15 patients (65%) experienced cough with the AeroTech II. Although these differences were statistically significant ($p = 0.014$), they did not have an impact on patient tolerance. Cough prevented treatment in only one patient (Patient 21) but with both nebulizers. One additional patient (Patient 3) experienced significant coughing with the AeroTech II (Cough Scale 3, more than four bouts), but was able to complete the treatment. The same patient found treatment more tolerable using the Respirgard II (Cough Scale 1, one to two bouts).

As originally suggested by laboratory testing, treatment time was considerably shortened utilizing the AeroTech II nebulizer. On the average, the AeroTech II was able to deliver its dose in half the time required by the Respirgard II ($p < 0.0001$). Because of the subjective nature of break periods, break time was not included when treatment time was calculated. Our experience with aerosolized pentamidine has been that breaks for cough, sips of water, and rest periods are not uncommon with the first few treatments. Break times are usually short (< 1 min) and do not greatly influence treatment time.

Finally, our results have potential implications for cost and convenience of therapy. Although this study did not include a cost analysis, one could estimate substantial differences in cost based on choice of nebulizer. Specifically, savings would be realized with regard to amount of drug and amount of time required by these treatments. Our clinic provides from 10 to 15 aerosolized pentamidine treatments in a given day, and has found it useful to have a choice of delivery systems. Almost all our patients tolerate the AeroTech II system, and they prefer the shorter treatment despite the increased risk of cough. However, for those patients, who are more sensitive to the treatment, the Respirgard II may be better tolerated.

ACKNOWLEDGMENTS

We thank Linda Zajicek RN for her assistance in organizing and conducting this study.

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Engineering and Administrative Controls To Contain Aerosolized Ribavirin: Results of Simulation and Application to One Patient

William Charney IH, Kevin J Corkery BS RRT, Roger Kraemer CRTT, and Lee Wugofski MD MPH

BACKGROUND: Concern persists over the possible effects of ribavirin exposure on health-care workers. Because personal protective equipment is considered the least appropriate control measure, we devised and evaluated a double-tent system to reduce caregiver exposure. MATERIALS & METHODS: We combined commercially available components (including tent canopy, oxygen hood, tubing, and vacuum units) to provide continuous exhaust and containment of ribavirin aerosol being administered to infants and children up to a weight of about 20 kg while maintaining a stable oxygen concentration. Administrative controls were invoked. Personal-breathing-zone sampling and area sampling were performed during a 5-hour simulation and during an 18-hour treatment period. RESULTS: No detectable levels of ribavirin were noted. CONCLUSION: These preliminary results suggest that health-care workers can be adequately protected by such controls. However, we emphasize that until further studies are performed using these controls, personal protective equipment should be mandatory for bedside health-care workers. (Respir Care 1990;35:1042-1048.)

Introduction

Ribavirin is an antiviral agent introduced in the past decade for the treatment of respiratory syncytial virus (RSV) infections in infants and children.[1] Although a number of clinically useful drugs are routinely administered by aerosolization, particularly for the treatment of bronchospastic disorders, ribavirin differs in that the particle size (mass median diameter 1.3μ)[2] allows deep penetration into the lung and administration usually occurs 12-18 hours daily for 3-7 consecutive days.[1] The drug has been shown to be teratogenic in some animal species,[3-7] and, consequently, concern over the occupational exposure of health-care workers has prompted medical centers to re-evaluate their policies on indications for and use of ribavirin.[8] Some have decided to provide respirators with protection factors of 10 or greater.[9] (The protection factor is the ratio of the concentration of a particular substance in ambient air to concentration inside the mask.)

Because personal protective equipment, or barrier protection (eg, a respirator), is considered the least appropriate control measure to protect someone from a potentially hazardous substance, and because the components of a respiratory protection program can

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be difficult to comply with,[10] a system that reduces occupational exposure to a level that eliminates the need for personal respiratory protection is desirable. A respiratory protection program involves semiannual fit-testing of the respiratory mask, annual medical surveillance of all personnel involved, employee instruction in the use of the mask and about the hazardous substances used, recordkeeping, safe storage of respirators not in use, and routine respirator inspection.[10] In our experience, the communication necessary among personnel in the Respiratory Care, Nursing, and Occupation Health and Safety Services to schedule and implement the many facets of a personal protection program is difficult and time-consuming to maintain.

Despite numerous investigations of health-care-worker exposure to ribavirin aersols,[2,9,11,12] no consensus has been reached concerning the precautions necessary for safe administration of this agent. The California Department of Health Services[13] has determined that an acceptable airborne ribavirin concentration can be calculated by applying an EPA (Environmental Protection Agency) safety factor of 1000 to the experimental No Observed Exposure Level (NOEL) for the most sensitive endpoint (the concentration at which an effect is seen) in the most sensitive species tested.[13,14] We adopted the NOEL observed by Harrison et al[11] for the rabbit (0.3 mg/kg) to estimate an acceptable airborne concentration for an 8-hour workshift as a time-weighted average (TWA) of 2.7 $\mu g/m^3$, assuming that the employee weighs 58 kg, has a minute ventilation of 19 L, and retains 70% of the inspired ribavirin. TWA is the average concentration of the substance in question to which nearly all workers may be exposed in an 8-hour workday without adverse effect. TWA assumes that workers are usually not exposed to a substance for their entire shift and is calculated by the equation:

$$TWA = \frac{(C_1 \cdot T_1) + (C_2 \cdot T_2) + (C_N \cdot T_N)}{T_{TOT}},$$

where C = concentration of substance being measured, T = time of exposure to substance being measured, T_{TOT} = total number of minutes worked on shift, and N = number of times exposed.

We measured the room concentration of ribavirin to be 456 μg during a 12-hour treatment when ribavirin was being administered directly into a mist tent (unpublished data, San Francisco General Hospital, 1989). In a preliminary study, we evaluated the Aerosol Delivery Hood System by ICN Pharmaceutical and found the highest concentration of ribavirin to be 36.2 $\mu g/m^3$.[3,15] We consider those two conditions to be unacceptable because ribavirin exposure was above 2.7 $\mu g/m^3$. The Aerosol Delivery Hood System may also have limited use due to the size of infants that it will accommodate. It has been a goal of our Health and Safety Service to work in conjunction with the Respiratory Care and Nursing Services to devise a method of administering ribavirin in a safe and efficient manner that would obviate the need for personal protective equipment. In this pilot study, we sought to determine whether the scavenging system that we constructed could decrease health-care-worker exposure to a ribavirin TWA of 2.7 $\mu g/m^3$ or less.

Materials and Methods

We assembled and evaluated a double containment system, which consists of a 25″ × 30″ × 28″ oxygen tent canopy* over a smaller 12″ × 12″ × 12″ oxygen hood as seen in Figure 1. A Small Particle Aerosol Generator (SPAG-2) delivers aerosolized ribavirin into one port of the hood at a flowrate of 12 L/min (nebulizer flowrate of 7 L/min plus a drying flow of 5 L/min). A heated and humidified gas

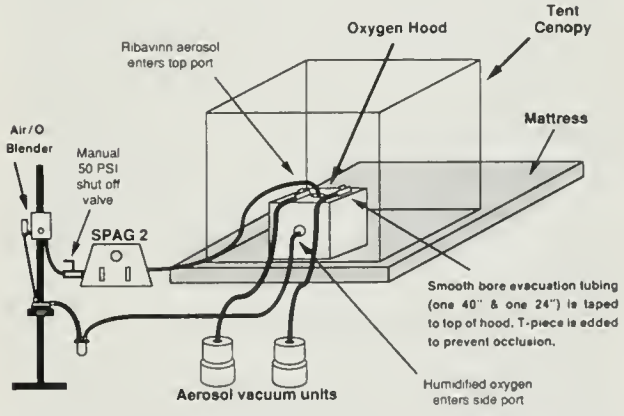
Tent Canopy
Oxygen Hood
Ribavirin aerosol enters top port
Mattress
Air/O Blender
Manual 50 PSI shut off valve
SPAG 2
Smooth bore evacuation tubing (one 40" & one 24") is taped to top of hood. T-piece is added to prevent occlusion.
Aerosol vacuum units
Humidified oxygen enters side port

Fig. 1. Containment system for the administration of ribavirin to nonintubated infants and small children.

mixture is supplied through the other port at a flowrate of 12 L/min to provide consistent oxygenation to the hood (and, thus, to the patient) when the SPAG-2 nebulizer is turned off. A single blender provides gas at a controlled concentration to the SPAG-2 and to the supplemental delivery system, which remains in continuous operation. The F_{IO_2} is continuously monitored with an IL 408 oxygen analyzer. The space between the tent canopy and the oxygen hood is evacuated continuously by two vacuum units equipped with high efficiency particulate (HEPA) filters. Two pieces of smooth-bore aerosol tubing, one 40″ and one 24″ in length, are attached at one end to the vacuum units and to aerosol T-adapters taped to the oxygen hood at the other end. The T-adapters decrease the likelihood of accidental occlusion. The SPAG-2 unit is equipped with a manual shut-off valve for easy interruption of aerosol delivery. The free edges of the tent canopy are tucked beneath the mattress to help eliminate leakage. The HEPA filters are replaced daily.

At the start of the tests, evacuation flow was measured at the T-piece end of the aerosol tubing. A Jaeger pneumotachograph (calibrated with a Fisher-Porter flowtube and a 1-L syringe) was used to measure flow. In order to determine whether the flow output of the vacuum units was reduced by the resistance offered by the pneumotachograph, we estimated flow indirectly by the following gas-dilution technique: A 40″, 22-mm ID smooth-bore tube was attached to a vacuum unit. A bleed flow of 10 L/min oxygen was delivered by a Porter flowtube to the distal end of the tube. The unit was turned on and the concentration of the evacuation flow was allowed to stabilize. The concentration of oxygen ($\%O_2$) in the evacuation flow was measured by mass spectrometer connected to a gas sampling port at the proximal end of the tube. The flow was calculated by the equations:

$$F\dot{V}_{evac_{O_2}} = \frac{(\dot{V}_{bleed})(F\dot{V}_{bleed_{O_2}}) + (\dot{V}_{amb})(F\dot{V}_{amb_{O_2}})}{\dot{V}_{bleed} + \dot{V}_{amb}},$$

and

$$\dot{V}_{evac} = \dot{V}_{bleed} + \dot{V}_{amb},$$

where $F\dot{V}_{evac_{O_2}}$ = fractional oxygen concentration of evacuation flow, $\dot{V}_{bleed}$ = bleed flow, $F\dot{V}_{bleed_{O_2}}$ = fractional oxygen concentration of bleed flow, $\dot{V}_{amb}$ = ambient flow, $F\dot{V}_{amb_{O_2}}$ = fractional oxygen concentration of ambient flow, and $\dot{V}_{evac}$ = evacuation flow. $\dot{V}_{bleed}$, $F\dot{V}_{bleed_{O_2}}$, $F\dot{V}_{amb_{O_2}}$, and $F\dot{V}_{evac_{O_2}}$ are known; the first equation is solved for $\dot{V}_{amb}$, and then the second equation is solved for $\dot{V}_{evac}$.

Personal and area monitoring samples were taken first during ribavirin administration to a simulated patient and later to a 2-month-old infant with RSV infection in the Medical-Surgical Intensive Care Unit. (Our institution does not have a separate pediatric intensive care unit.) For the simulation, the test system was set up and three 5-hour area samples and one 100-minute personal sample were taken. For the patient application, ribavirin administration was begun at 21:00 on one evening and discontinued at 15:00 the following day. This was the patient's fifth and final dose of ribavirin. The first four doses had been administered through the patient's endotracheal tube via mechanical ventilator. The patient continued to improve and was discharged from the ICU the morning following the fifth ribavirin treatment. The patient was discharged from the hospital 2 days later.

Three health-care workers were equipped with sample pumps with filters positioned within their breathing zone (ie, filters were placed on their collars) and were monitored over two shifts. In addition, area sampling was performed at the head of the bed, 6 feet above floor level—the location considered to be in the breathing zone of persons who might be in the room but not directly attending the patient. The health-care workers were instructed to shut off the nebulizer with the manual cutoff valve 5 minutes before breaking into the system for patient care activities. The log indicated that compliance was universal, and the 5-minute delay posed no problems during the course of treatment. Interruptions in aerosol administration were logged for the 18-hour period (Table 1). All bedside personnel (nurses and therapists) were required to wear a fit-tested disposable respirator with a personal protection factor (PPF) of 10. Fit-testing was performed according to OSHA Standard 1910.134(e)(5).[10] No other persons were allowed to enter the patient's room during the time that ribavirin was being administered.

Airborne ribavirin samples were collected on Gelman 37-mm glass fiber filters with a cellulose ester backup pad in a 2-piece cassette using an ALPHA-1 Air Sampler. Pump samples were collected at an average flowrate of 2 L/min for all samples. Pumps were calibrated using a Gilibrator Standard System

Table 1. Aerosol Interruptions and Total Exposure Time during 18-Hour Treatment

Time Off-On	Total Minutes Off
Night Shift	
22:18-22:38	20
22:57-23:00	3
24:00-00:20	20
01:25-01:40	15
03:35-04:05	30
05:25-05:40	15
06:20-06:45	25
Number of interruptions = 7	128
Day Shift	
08:42-08:59	17
09:20-09:45	25
10:00-10:30	30
13:00-13:30	30
Number of interruptions = 4	102
Replacement Nurse Day Shift	
10:24-10:42	18
Number of interruptions = 1	18

(a calibration method that utilizes a primary flow calibrator and a bubble generator) and were checked periodically in the field with a rotameter calibrated against the Gilibrator standard.

The rooms in the ICU are designed for 'positive pressure' ventilation, with approximately 6.5 air exchanges/hour (350 cfm supply, 300 cfm exhaust). Ventilation is by dispersion airflow through the perforated ceiling in a room with a volume of approximately 3200 ft^3. The positive pressure design is intended to prevent the transmigration of microorganisms into the ICU rooms. Although some might consider it more desirable to administer ribavirin in a room with 'negative pressure' ventilation, such a room was not available to the patient at the time of this pilot study.

Samples were analyzed by high performance liquid chromatography according to the NIOSH Method 5027. As part of the laboratory's procedure, a spike sample (a known amount of ribavirin) and a blank sample (containing no ribavirin) are analyzed concurrently with the test samples, to verify test results. Detection limits for this analysis are variable due to differences in total volume collected for each sample. Detection limit for sample volume collected appears in Table 2. The volume collected varied according to the worker's exposure. The greater the volume of air drawn through the sample pump, the lower the detection limit. The lowest level of detection (LOD) for this method is 0.7 μg/sample.

Results

The mean (SD) evacuation flowrate for each vacuum unit was 91 (1.1) L/min when measured by the Jaeger pneumotachograph and 97 (1.1) L/min when measured by gas dilution.

No other personnel entered the room during ribavirin administration. The oxygen concentration in the hood (35%) was unaffected by the evacuation flow.

Ribavirin was not detected in area or personal-breathing-zone samples. Table 2 provides the exposure time, sample pump flowrate, volume of air passed through the pump filters, and the detection limit of the analytical method based on the volume collected.

No special patient surveillance measures—other than the continuous electrocardiographic, oxygen-concentration, and pulse-oximetry monitoring routinely performed on ICU patients—was deemed necessary.

Discussion

Environmental levels measured in a California State Department of Health's Field Investigation[13] have demonstrated that the total weighted average (TWA) of 2.7 $\mu g/m^3$ (or lower) can be achieved during patient administration via a mechanical ventilator equipped with appropriate filters. For patients who are not intubated, some success in reducing environmental levels has been reported[16] utilizing the Aerosol Delivery Hood System developed by the manufacturers of ribavirin, but application of this system is limited to small infants

Table 2. Personal and Area Sampling Results from Bench Testing and Patient Application

Filter #	Sample	Exposure Time (Minutes)	Pump Flow Rate (L)	Volume Collected (L)	Detection Limit ($\mu g/m^3$)	Results
Bench Data						
1	Top of oxygen hood, center	300	2	600	3.93	ND†
2	Top of oxygen hood, right	300	2	600	3.93	ND
3	Top of oxygen hood, left	300	2	600	3.93	ND
4	Personal sample, center	100	2	200	11.8	ND
Patient Data						
8199 GF1	Personal-night shift/day	218	2	436	5.41	ND
8200 GF3	Personal-day shift	440	2	880	2.68	ND
8201 GF2	Area sample night shift/day	630	2	1260	1.87	ND
8202 GF4	Area sample day shift	440	2	880	2.68	ND
8203 GF5	Personal replacement	300	2	600	3.93	ND

†ND = none detected.

(less than about 6 kg in weight). In addition, environmental levels measured and reported in a preliminary study suggest that personal protection equipment may still be needed.[15] The highest airborne concentrations (area samples of 557 $\mu g/m^3$ reported by Gladu and Ecobichan[12] and 317 $\mu g/m^3$ reported by the California Department of Health[13]) have been seen when the drug has been administered by simple oxygen tent. Because patients with RSV may be treated with ribavirin in an attempt to avoid intubation, institutions have had to provide personal respiratory protection to employees to prevent excessive exposure.

The numerous components of a personal respiratory protection program must be adhered to if the employer supplies respirators to personnel. In addition to the necessary training and medical evaluation, each employee must be fit-tested semiannually so that adequate protection can be empirically demonstrated and inappropriate use and a false sense of security can be avoided.

Since the Fall of 1989, our institution has been fit-testing employees involved in ribavirin administration, and has found that five different brands of respirators (nonpowered, air-purifying type, equipped with HEPA filters) of various sizes are required to properly fit the diverse work force. The OSHA proscription of most types of facial hair because of the hair's interference with an adequate respirator seal has further complicated fitting and staffing. Powered air-purifying respirators may address some of these concerns, but their substantial cost and noisiness may limit their usefulness. Use of disposable respirators such as the 3M 9970 has certain advantages in that they may be less offensive to the wearer and cause less concern to the patient's family, but they too require following the OSHA Standard 1910.134(e)(5) for fit-testing.[10]

The system evaluated in this study differs from those previously reported[12,15,16] in incorporating two separate evacuation components, each utilizing high efficiency filters (99.97% efficient with aerosol of mass median diameter 0.3 μ). Our experience with the simulated patient encouraged us to try the system on patients requiring ribavirin. Unfortunately for our experimental purposes and fortunately for our patient population, only the one patient reported here required ribavirin administration between January 1 and June 1, 1990.

The fact that no ribavirin was detected, in our opinion, is due to exhaust volume and the integrity of the HEPA filters. We had used the same sampling

technique for measuring and the same laboratory for analyzing ribavirin during two previous studies (unpublished data) that did not utilize the same engineering and administrative controls. Ribavirin was detected during those studies. Samples collected by the same sampling technique and analyzed by the same laboratory in studies by another large medical center in the Bay Area have yielded ribavirin concentrations (personal communication, Steven Henperly, Industrial Hygienist, Kaiser Medical Center-San Francisco, 1990). We believe that the combination of the high evacuation flow in the double-tent system and the 5-minute interval of no aerosolization before the tent is opened allows the ribavirin to be scavenged through the HEPA filters. It may be difficult to adhere to the 5-minute shut-off stipulation if a number of ribavirin treatments are occurring simultaneously and an emergency situation arises. Further evaluation of this technique is necessary before personal respiratory protection can be eliminated.

The evacuation flow measurements suggest that the vacuum unit is sensitive to the resistance of the evacuation tubing. Flow measured by the pneumotachograph was lower than flow estimated by gas dilution. Total evacuation flow from the two units estimated by gas dilution dropped from 194 to 144 L/min when the units were bench tested with a 6-ft corrugated aerosol tube in place of the smooth-bore tube. This suggests that any change in circuit resistance (increasing the length of the evacuation circuit; using corrugated tubing, which causes turbulent flow; partially blocking the tubing with bedsheets; or crimping tubing with the bedrail) could lower evacuation flow and increase the risk of ribavirin exposure. This emphasizes the importance of maintaining a high evacuation flow and of measuring the flow before initiating ribavirin aerosolization.

In Conclusion

Our system appears to maintain environmental levels of ribavirin at or below the time-weighted average recommended by the California State Deaprtment of Health. With airborne levels kept at the range detected in this evaluation, rooms with negative air pressure relative to outside halls may not be necessary.

Our preliminary results suggest that personal protective devices (ie, respirators) may not be needed if the double-tent system and the administrative measure of shutting off the aerosol generator for 5 minutes prior to opening the tent for patient care is followed. The efficacy and importance of interrupting aerosolization to allow proper evacuation and settling time cannot be overemphasized. We still require personnel to use respirators when administering ribavirin to non-intubated patients. Until more results with this system have been reported from our institution or others, we will require the wearing of the respirator.

Finally, the risk of ribavirin exposure to the developing fetus has not been established. We believe that employees who are pregnant or who are actively attempting to conceive should be assigned to areas of the hospital in which ribavirin exposure will not occur.

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PRODUCT AND SERVICE SOURCES

Hoods and Tents:

Oxygen tent canopy,THS 523, Tri-Anim Health Services Inc, Glendale CA

Oxygen hood, Tot Hut #1001, Peace Medical, West Orange NJ

Aerosol delivery system,#6005, ICN Pharmaceuticals Inc, Costa Mesa CA

Evacuation Components:

Vacuum units, #4031, ICN Pharmaceuticals Inc, Costa Mesa CA

22-mm smooth-bore tubing, Corr A Tube II Part 1413, Hudson Oxygen, Temecula CA

Aerosol Generator:

Small Particle Aerosol Generator, SPAG-2, ICN Pharmaceuticals Inc, Costa Mesa CA

Calibration Devices:

Jaeger pneumotachograph, Jaeger Medical Instruments GmbH & Co KG, Hoechberg, Germany

1-L syringe, Jaeger Medical Instruments GmbH & Co KG, Hoechberg, Germany

Flowtube, FP1/2GS-27-G-10 Float 1/2GSVT45A, Fisher-Porter Co, Warminster PA
Flowtube, R-104, Porter Instrument Co, Hatfield PA
Precision Rotameter, BGI Inc, Waltham MA
Gilibrator Standard System, P/D 800-26 and P/D 800-2868N, Gilian Instrument Corp, Wayne NJ

Analytical Equipment:
Gelman 37-mm glass fiber filters, Type A/E#61652 micron nominal pore size, Alpha Biomedical, Petaluma CA
Alpha-1 Air Sampler, DuPont Instrument Systems, Kennett Square PA
Mass spectrometer, Perkin-Elmer, Pomona CA

Liquid Chromatography:
Alpha Chemical and Biomedical Laboratory, Petaluma CA

Respirators:
Disposable respirator, 3M 9970, 3M, St Paul MN
Permanent respirator, Wilson Half Mask Respirator #6140, Pedley-Knowles, San Francisco CA

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Comparison of the Effects of Pressure Support Ventilation Delivered by Two Ventilators

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BACKGROUND: Although numerous descriptions of the clinical application of pressure support ventilation (PSV) have been published, few studies have compared delivery by different ventilators. We compared the efficacy of PSV as provided by the Hamilton Veolar and the Puritan-Bennett 7200a in 8 patients. METHODS: Patients were randomized to receive PSV initially by the Veolar (Group I) or 7200a (Group II) at PSV_{max} (PSV set to deliver V_T = 10-12 mL/kg and $f < 20$). After 2 hours, patients were switched to the opposite ventilator and after a 2-hour period on the second ventilator were switched back to the initial ventilator for 2 more hours. The last 30 minutes of each 2-hour period were used for data collection. During data collection, ventilatory volumes, respiratory frequency, inspiratory time, airway pressures, oxygen consumption, carbon dioxide production, and arterial blood gases were measured. RESULTS: During ventilation with the 7200a, patients received a significantly larger tidal volume, or V_T, (for Group I, $p < 0.017$; for Group II, $p < 0.028$) and longer inspiratory time, or T_I, (for Group I, $p < 0.023$; for Group II, $p < 0.031$) compared to ventilation with the Veolar. Other measured variables (including blood gases, minute ventilation, and respiratory frequency) were unchanged. CONCLUSION: The 7200a provides a longer T_I and larger V_T than does the Veolar due to its lower inspiratory termination criterion (5 L/min vs 25% of peak flow). Both ventilators perform well in the PSV mode, and no clinically appreciable differences were noted. (Respir Care 1990;35:1049-1055.)

Introduction

Pressure support ventilation (PSV) is a patient-triggered, pressure-limited, flow-cycled mode of ventilatory support introduced in 1986 by MacIntyre.[1] Since then, its popularity and application have rivaled those of intermittent mandatory ventilation (IMV) during the 1970s. Although numerous descriptions of the clinical use of PSV have been published,[1-6] a paucity of information exists comparing the efficiency of PSV delivery by different ventilators.[7,8] We designed a study to compare PSV delivered by

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Abbreviations Used in This Paper

AMV	— Assisted mechanical ventilation
auto-PEEP	— Spontaneous, or intrinsic, PEEP
CPAP	— Continuous positive airway pressure
EE	— Energy expenditure
f	— Respiratory frequency
IMV	— Intermittent mandatory ventilation
$\bar{P}_{aw}$	— Mean airway pressure
PEEP	— Positive end-expiratory pressure
PIP	— Peak inspiratory pressure
PSV	— Pressure support ventilation
PSV_{max}	— Maximum pressure support ventilation
SIMV	— Synchronized intermittent mandatory ventilation
T_I	— Inspiratory time
T_{TOT}	— Total cycle time
$\dot{V}_{CO_2}$	— Carbon dioxide production
V_D/V_T	— Dead-space-to-tidal-volume ratio
$\dot{V}_E$	— Minute ventilation
$\dot{V}_{O_2}$	— Oxygen consumption
V_T	— Tidal volume
WOB	— Work of breathing

A Guide to the Use of SI in This Paper*

The SI unit for pressure is the kilopascal (kPa).
(cm H_2O)(0.098 06) = kPa.
(torr)(0.133 3) = kPa.

*For further information on SI (le Systeme International d'Unites), see Respir Care 1988;33:861-873 (October 1988) and Respir Care 1989;34:145 (February 1989—Correction).

the Hamilton Veolar* and the Puritan-Bennett 7200a, the two ventilators commonly used in our institution to provide PSV. Our goal was to determine whether any advantages or disadvantages could be attributed to either ventilator's method of PSV delivery.

System Descriptions

The Hamilton Veolar is capable of delivering PSV at up to 50 cm H_2O [4.9 kPa] in the spontaneous or SIMV modes. Inspiration is initiated when the patient exceeds the adjustable pressure trigger set by the operator. Once inspiration begins, flow increases to meet patient demand and to reach clinician-set pressure. Inspiration is terminated when the flow necessary to maintain the desired pressure is 25% of peak flow. If inspiratory time exceeds 3.0 seconds, inspiration is terminated, and in the event of apnea a backup mode of ventilation prevails.

The Puritan-Bennett 7200a can provide PSV at up to 70 cm H_2O [6.9 kPa] in the CPAP or SIMV mode. Inspiration begins when the patient's inspiratory effort exceeds the set adjustable pressure trigger. Flow is servo-controlled to achieve and maintain the desired peak pressure. Inspiration is terminated when required flow falls below 5 L/min. Inspiration may also be terminated if system pressure increases 1.5 cm H_2O [0.1 kPa] above set pressure or inspiratory time exceeds 3.0 seconds. Backup ventilation prevails in the event of apnea.

The ventilators used in the study had recently been calibrated by a manufacturer-trained technician. Immediately prior to use, ventilators were tested according to manufacturers' recommendations and any required bedside calibration was performed.

Methods

Eight patients requiring ventilatory support with PSV were studied. Patients were clinically stable and considered to be early in the weaning phase, but none was deemed ready for extubation. All patients were awake and alert, with an intact ventilatory drive. The mean (SD) F_{IO_2} for the study group was 0.38 (0.04) with a range 0.35 to 0.45. All patients were receiving 5 cm H_2O [0.5 kPa] PEEP, the minimum PEEP level used in our institution according to protocol. Table 1 describes the patients in detail. Patients were randomized to receive PSV initially via the Veolar (Group I, n = 4) or the 7200a (Group II, n = 4) using the PSV_{max} technique described by MacIntyre:[1] PSV was set to deliver a tidal volume (V_T) of 10-12 mL/kg and maintain respiratory frequency (f) < 20 breaths/min. Sensitivity was set at the minimum level that did not produce autocycling (approximately -0.5 to 1.0 cm H_2O [-0.05 to 0.10 kPa]). A backup rate sufficient to provide a minute ventilation ($\dot{V}_E$) equal to the patients' $\dot{V}_E$ during PSV was set to avoid hypoventilation in the event of apnea. No patient

*Suppliers are identified in the Product Sources section at the end of the text.

invoked the backup rate during the study. Patients were maintained on the first ventilator for 2 hours, after which they were placed on the second ventilator. They remained on the second ventilator for 2 hours at identical settings. After this period of ventilation, patients were returned to the initial ventilator for a third 2-hour period of ventilation. By alternating periods of ventilation in this manner, we hoped to eliminate potential differences seen solely due to changes in patient condition.

During each 2-hour study period, patients were continuously monitored by their respective ventilator monitoring system. The last 30 minutes of each study period were used for data collection. During this 30-minute period, a pneumotachograph was placed between the patient's endotracheal tube and the ventilator circuit to monitor V_T, $\dot{V}_E$, and inspiratory and expiratory flow. Inspiratory time (T_I) and f were calculated from recordings of inspiratory and expiratory flow as a function of time.

Airway pressure was monitored with a Bunnell airway pressure monitor, and peak (PIP), mean ($\bar{P}_{aw}$), and end-expiratory (PEEP) pressures were recorded. Oxygen consumption ($\dot{V}_{O_2}$), carbon dioxide production ($\dot{V}_{CO_2}$), and energy expenditure (EE) were continuously monitored by collecting and analyzing expired gas using an indirect calorimeter. Arterial blood was sampled from indwelling catheters and analyzed for pH, P_{aCO_2}, P_{aO_2}, and S_{aO_2}, at patient body temperature using accepted technique. Dead-space-to-tidal-volume ratio (V_D/V_T) was determined at the end of each 30-minute data-collection period, following a 5-minute collection of expired gas. Additionally, electrocardiogram (ECG), blood pressure, and heart rate were continuously monitored according to our normal intensive care unit practice. Patients were suctioned as needed during the study. Ventilator settings and medical management (eg, fluids and nutrition) remained consistent during the 6-hour study period. Analysis of variance was performed using commercially available software.

Table 1. Description of Study Patients

Patient Number	Age	Sex	Diagnosis	Duration of Ventilation* (days)
Group I				
1	39	M	Liver laceration Pneumonia	14
2	52	F	Flail chest Pulmonary contusion	14
3	71	F	Multiple long bone fractures, COPD	17
4	40	F	Cirrhosis Pneumonia	14
Group II				
5	56	M	Post-esophagectomy ARDS	20
6	35	F	Multiple stab wounds ARDS	10
7	24	M	Ruptured diaphragm ARDS	9
8	44	F	Pulmonary contusion Fractured sternum	12

*Prior to PSV study.

COPD = chronic obstructive pulmonary disease.

ARDS = adult respiratory distress syndrome.

Results

Tables 2 and 3 summarize the study results. In both groups, ventilation with the 7200a resulted in

Table 2. Summary of Study Results for Group I,* Those Receiving PSV by Veolar First

Variable	Veolar	7200a	Veolar
V_T (mL)	724 (39)	815 (32)†	736 (43)
f (breaths/min)	17 (4)	14 (3)	17 (3)
$\dot{V}_E$ (L/min)	12.3 (2)	11.4 (1.4)	12.5 (2)
P_{aCO_2} (torr)‡	41 (5)	42 (6)	41 (6)
P_{aO_2} (torr)	87 (12)	93 (9)	91 (14)
$\dot{V}_{O_2}$ (mL/min)	296 (28)	309 (25)	289 (34)
V_D/V_T	0.45 (0.7)	0.42 (0.08)	0.46 (0.11)
T_I (s)	1.06 (0.2)	1.32 (0.3)§	1.01 (0.3)

*n = 4. Values are mean (SD).

†p = 0.017 compared to the other ventilator.

‡See Box for SI conversions.

§p = 0.023 compared to the other ventilator.

Table 3. Summary of Study Results for Group II,* Those Receiving PSV by 7200a First

Variable	7200a	Veolar	7200a
V_T (mL)	826 (41)	751 (22)†	820 (30)
f (breaths/min)	15 (3)	17 (4)	15 (2)
$\dot{V}_E$ (L/min)	12.4 (2)	12.9 (2)	12.3 (1.5)
P_{aCO_2} (torr)‡	43 (4)	42 (4)	44 (3)
P_{aO_2} (torr)	104 (16)	107 (11)	103 (18)
$\dot{V}_{O_2}$ (mL/min)	315 (39)	320 (31)	329 (42)
V_D/V_T	0.51 (0.09)	0.54 (0.07)	0.52 (0.08)
T_I (s)	1.44 (0.3)	1.25 (0.02)§	1.38 (0.02)

*n = 4; values are mean (SD).

†p = 0.028 compared to the other ventilator.

‡See Box for SI conversions.

§p = 0.031 compared to the other ventilator.

a significant increase in V_T and T_I compared to ventilation with the Veolar at the same level of PSV. Group I required PSV at mean (SD) pressure of 21 (6) cm H_2O [2.1 (0.6) kPa] and Group II at 25 (8) cm H_2O [2.5 (0.8) kPa]. Because V_T was larger with the 7200a, a slight trend toward a decreased $\dot{V}_E$ and f with the 7200a was seen, but this did not reach statistical significance (p = 0.27 and p = 0.34, respectively). A trend for V_D/V_T to be lower during ventilation with the 7200a was seen, but this was not statistically significant. No clinically important or statistically significant differences were seen in other measured variables.

No patient professed preference for a particular ventilator, and observation of patient comfort revealed no striking differences. The Veolar provided a slightly higher peak flow than the 7200a (84 [15] L/min vs 76 [17] L/min, p = 0.19). We also noted that one patient in each group appeared to have air trapping as evidenced by initiation of inspiration prior to cessation of expiratory flow. Our initial protocol had not included a search for or measurement of auto-PEEP. The presence of auto-PEEP was detected after the study was finished, from strip-chart recordings of airway pressure, volume, and flow. Both these patients were ventilated with the 7200a. Using flow and airway pressure tracings, we measured auto-PEEP of 2 cm H_2O [0.2 kPa] and 4 cm H_2O [0.4 kPa] in these two patients. No adverse effects were attributable to this phenomena. We did not observe auto-PEEP in any patient on the Veolar.

Discussion

The current body of literature suggests that PSV can reduce ventilatory work loads, prevent diaphragmatic fatigue, compensate for additional work caused by poorly functioning demand valves and small endotracheal tubes, improve patient-ventilator synchrony, and facilitate weaning.[1-6] Most of this evidence comes from descriptive studies and, therefore, is open to criticism. No prospective randomized studies comparing PSV to either IMV or assisted mechanical ventilation (AMV) have been done, and future studies are not likely. Regardless of the absence of scientific scrutiny, PSV is a popular, widely used mode. This fact alone requires that further study into the mechanics of PSV be undertaken. Our study was intended to determine whether differences in the delivery of PSV by these two ventilators affected patient response. Complete understanding of potential differences requires that delivery of a PSV breath be analyzed in component parts. MacIntyre suggests that the ideal PSV breath consists of five components or phases: (1) triggering inspiration, (2) rise to set pressure, (3) pressure plateau, (4) termination of inspiration, and (5) return to baseline (expiratory time) (Fig. 1). Each of these will be considered in light of the study results and published findings.

The initiation of inspiration by triggering, or cycling-on, the ventilator is not unique to PSV. In fact, numerous investigations have been published regarding the triggering characteristics of demand valves during SIMV and their contribution to the work of breathing (WOB).[10-14] With PSV the same principles apply—that is, insensitivity (caused by improper setting by the clinician, poor measurement and response by the ventilator, or the presence of auto-PEEP) will increase WOB and lead to patient-ventilator dysynchrony and eventual intolerance of ventilatory mode.[15] Kacmarek studied the difference in imposed WOB during PSV in six ventilators, and found no clinically significant differences among them.[16] In this study, the Veolar and 7200a performed comparably. This is consistent with our findings in that we did not detect changes in WOB between the two ventilators (as evidenced by patient comfort and f) and $\dot{V}_{O_2}$ did not change.

Time to reach plateau pressure or "rise time" is essentially a reflection of ventilator flowrate. Early descriptions of PSV suggested that rapid rise to pressure using high flowrates was optimal. In the study by Kacmarek,[16] the Siemens 900C demonstrated a flowrate of 94 L/min compared to its next closest competitor, the BEAR 5 at 70 L/min. The Veolar and 7200a had flowrates of 69 and 61 L/min, respectively. This finding is also in concert with ours. Recently, several authors have described the beneficial effects of a variable flowrate and hence variable rise time on patient V_T, f, and comfort during PSV.[17–20] If ventilator flowrate exceeds patient demand, inspiration will be terminated prematurely. This applies to ventilators that end inspiration when flow falls to a predetermined percentage of initial peak flow. If patient demand exceeds ventilator flow, then work of breathing will increase as described by Marini et al[21] during AMV. It seems prudent then to allow ventilator flow to be tailored to patient demand during PSV. Patients with high ventilatory drives would receive their required high flow, and those with lower demands would receive reduced flow to optimize V_T and f. At present, only the IRISA ventilator allows a variable flowrate during PSV. Similar results can be obtained using the Siemens 900C, by reducing ventilator working pressure.[18,19] Reducing working pressure causes flowrate to decrease, and time to reach the set pressure is lengthened. Our study shows that rise to set pressure is similar with the Veolar and 7200a.

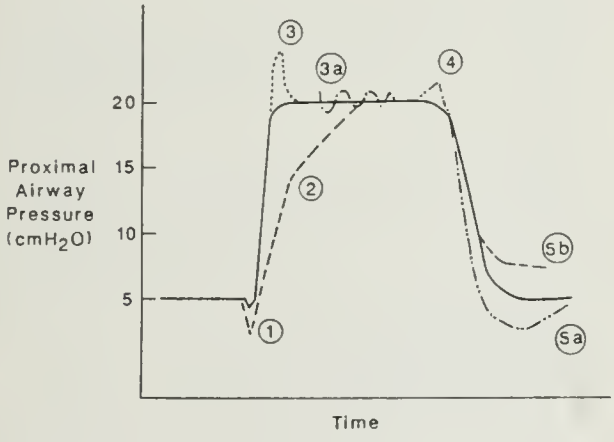

Fig. 1. Schematic of the components of a pressure-supported breath. The solid line represents the ideal PSV breath. Dotted lines reveal deviations from the ideal due to technical limitations. (1) Represents improper sensitivity setting or inadequate ventilator response. (2) Represents insufficient flow from the ventilator to meet patient demand. (3) Represents flow in excess of patient demand resulting in overshoot of the preset pressure. (3a) Represents oscillating airway pressure due to variations in ventilator flowrate in the attempt to maintain constant pressure. (4) Represents patient expiratory effort prior to termination of inspiration. (5a) Represents pressure below baseline resulting from continued patient inspiration. (5b) Represents auto-PEEP. (Adapted, with permission, from Reference 9.)

Time at the preselected pressure is a function of ventilator flowrate, patient demand, and the criterion for terminating inspiration. This time at the preselected pressure varies from breath to breath. Occasionally, oscillations in the proximal airway pressure waveform can be seen during the plateau phase. This occurs when gas flow from the ventilator fluctuates in an attempt to maintain a constant airway pressure. We did not observe this with either ventilator.

The basis for the termination of inspiration appears to be the only difference in PSV delivery by the two ventilators studied. Because of the inspiratory termination criterion of 5 L/min flow, all patients had significantly larger V_T when ventilated with the 7200a. This was accompanied by a trend towards a decreased f and $\dot{V}_E$. However, aside from the increase in V_T, no other differences were noted. Our data agree with those of Ho and MacIntyre,[17] who compared variable inspiratory termination criteria. Using a BEAR 3 with a variable inspiratory termination of 50% or 25% of peak flow, they found no differences in V_T, f, or patient comfort. Braschi et al[22] modified a Veolar to terminate inspiration at 3%, 10%, 19%, 25%, 35%, or 56% of peak flowrate, and found significant increases in T_I alone and T_I as a function of total cycle time (T_I/T_{TOT}). They suggested that varying inspiratory termination may be an important feature of future PSV systems. Our results and those of Ho and MacIntyre are contrary to those of Braschi et al; however, the difference may be due to the wider range of termination criteria (3-56%) available in the Braschi study.

We were puzzled by the presence of auto-PEEP in two patients ventilated with the 7200a because PSV should allow the patient to control ventilatory timing. However, the amount of auto-PEEP was small, and did not appear to adversely affect inspiratory trigger or patient comfort. Brochard et al[7] noted the presence of auto-PEEP of similar

magnitude in nine patients ventilated with PSV. Interestingly, they found that for the same level of PSV, the three ventilators tested (Engstrom Erica, Siemens 900C, and Ohmeda CPU-1) produced different levels of auto-PEEP. The authors offered no explanation for the presence of auto-PEEP or the differences between ventilators. We believe that development of auto-PEEP is a function of patient dynamics, inspiratory termination criteria, and resistance to expiration posed by the exhalation valve. The development of auto-PEEP could lead to an increase in the work of breathing and pulmonary barotrauma. Our patient population consists mainly of surgery and trauma patients who are not predisposed to the development of auto-PEEP.[23] It is quite possible that the late inspiratory termination criteria of the 7200a might lead to clinically significant levels of auto-PEEP in a group of patients with COPD. This is, however, only speculative and requires further study in such a group of patients. Return of pressure to baseline is also a function of three variables monitored. Aside from the development of auto-PEEP, this component of the PSV breath may be affected by continued patient effort (Fig. 1). If inspiration is terminated prematurely, then the patient may continue to demand flow from the system during ventilator expiration, distorting the pressure waveform. This would result in an increase in the WOB, patient discomfort, and patient-ventilator dysynchrony.

Conclusion

Our study failed to demonstrate any clinically important differences in PSV as delivered by either the Veolar or 7200a. Both ventilators performed properly, and no adverse effects were encountered during the study. We conclude that PSV with these two ventilators provides comparable ventilation and oxygenation and that varying inspiratory termination between 25% of peak flowrate and terminal flow of 5 L/min does not result in any clinically important differences in this small group of patients. Comparison of these two ventilators in a group of patients at risk for developing auto-PEEP might unmask differences not detected in this study. Future research of PSV should include characterization of different ventilator systems, determination of proper inspiratory flow settings, and appropriate clinical applications.

PRODUCT SOURCES

Airway Pressure Monitor:
Bunnell Airway Pressure Monitor, Mallinckrodt Critical Care, Glen Falls NY

Differential Pressure Transducer:
Validyne MP-45, Validyne Engineering Corp, Northridge CA

Indirect Calorimeter:
MMC Horizon, SensorMedics Corp, Yorba Linda CA

Pneumotachograph:
Hans-Rudolph 3200, Hans Rudolph Inc, Kansas City MO

Statistical Software:
Micro Stat, Ecosoft Inc, St Joseph MI

Ventilators:
Hamilton Veolar, Hamilton Medical, Reno NV
7200a, Puritan-Bennett Corp, Carlsbad CA

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CORRECTION

An error occurred in Salyer and Chatburn's paper "Patterns of Practice in Neonatal and Pediatric Respiratory Care" (Respir Care 1990;35:879-888). Responses to the question "Do You Both Heat and Humidify Gas Delivered to Neonates via Resuscitation Bags?" (Page 884, Table 5) were incorrect. The correct responses are Yes 6% and No 94%. We regret the error.

Altering Flowrate during Maximum Pressure Support Ventilation (PSV_{max}): Effects on Cardiorespiratory Function

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BACKGROUND: We studied the cardiorespiratory effects of altering ventilator-set inspiratory flowrate ($\dot{V}_{vent}$) during pressure support ventilation (PSV) in 15 patients using the tRISA microprocessor-controlled ventilator. METHODS: All patients were being ventilated at PSV_{max} (ie, PSV level adjusted to provide tidal volume [V_T] = 10-12 mL/kg and f $\leq$ 20 breaths/min) following a mean (SD) duration of ventilatory support of 16.1 (7) days. Patients were initially ventilated with the maximum $\dot{V}_{vent}$ for 1 hour. During this hour, tidal volume, inspiratory time (T_I), minute ventilation ($\dot{V}_E$), respiratory frequency (f), oxygen consumption ($\dot{V}_{O_2}$), heart rate, and mean arterial blood pressure were monitored continuously. Additionally, at the end of the 1-hour period, arterial blood gas analysis and expired-gas collection for calculation of dead-space-to-tidal-volume ratio were performed. Patients were then ventilated at the lowest $\dot{V}_{vent}$ that would maintain PSV_{max}, and measurements were repeated. A third, midrange $\dot{V}_{vent}$ was then used, and measurements were repeated after 1 hour. RESULTS: A variable response to alterations in $\dot{V}_{vent}$ was observed. Four patients exhibited a lower f, longer T_I, and larger V_T at the highest $\dot{V}_{vent}$; four at the lowest $\dot{V}_{vent}$; and seven patients at the midrange $\dot{V}_{vent}$. Patients with the highest $\dot{V}_E$ preferred the highest $\dot{V}_{vent}$ and decreasing $\dot{V}_{vent}$ in this population resulted in tachypnea and dysynchrony. When $\dot{V}_{vent}$ was increased in the group preferring the lowest $\dot{V}_{vent}$, T_I and V_T fell while f increased. No clinically important changes were seen in pulse rate or mean arterial blood pressure in any patient during the $\dot{V}_{vent}$ manipulation. CONCLUSION: Variable $\dot{V}_{vent}$ during PSV allows titration of ventilator output to patient demand, improves patient-ventilator synchrony, and should be incorporated into current PSV systems. (Respir Care 1990;35:1056-1064.)

Mr Branson is Clinical Instructor, Mr Campbell is Critical Care Coordinator, Dr Davis is Assistant Professor of Surgery, Dr Johannigman was a Fellow, Dr Johnson is Assistant Professor of Surgery, and Dr Hurst is Associate Professor of Surgery and Anesthesia and Director of Division of Trauma and Critical Care — Departments of Surgery and Respiratory Care, University of Cincinnati Medical Center, Cincinnati, Ohio. Dr Johannigman is now Captain and Director, Intensive Care Services, Department of Surgery, Wilford Hall, United States Air Force, San Antonio, Texas.

The views expressed in this article are those of the authors and do not reflect the official policy or position of the Air Force, Department of Defense, or U.S. Government. None of the authors has a financial interest in the reported products or the companies represented.

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Introduction

Pressure support ventilation (PSV) is a patient-triggered, pressure-limited, flow-cycled mode of ventilatory support introduced by MacIntyre in 1986.[1] Pressure-supported breaths are generally characterized by an initial deflection below baseline, caused by patient inspiratory effort, followed by a rapid rise to selected peak pressure. Inspiration is terminated when flow falls to a predetermined percentage of initial peak flowrate or to a predetermined terminal flowrate. Although different criteria to terminate inspiration are incorporated into various ventilators, virtually all have a nonadjustable, rapid rise to selected pressure.[2] The IRISA ventilator* is a new microprocessor-controlled ventilator that allows a variable inspiratory flowrate during PSV. We undertook this study to determine whether variations in ventilator-set inspiratory flowrate during PSV would affect ventilatory, hemodynamic, and blood gas variables.

Methods

We studied 15 patients who required ventilatory support and were being ventilated in the PSV mode. Table 1 describes the patient population in detail. All patients were recovering from their primary illness and were judged by the staff to be in the weaning phase of their ventilatory support course, although none was judged ready for extubation. Prior to beginning the study, we calculated dynamic characteristic (Ch_{dyn}) and effective static compliance (C_{FS}):

$$Ch_{dyn} = \frac{V_{T\,measured}}{PIP \quad EEP},$$

and

$$C_{FS} \quad \frac{V_{T\,measured}}{P_{plateau} \quad EEP},$$

where PIP is peak inspiratory pressure, $P_{plateau}$ is the pressure at the end of airway occlusion or inspiratory pause, and EEP is end-expiratory pressure. We measured the variables for each patient by delivering a mandatory breath from the ventilator at a V_T of 12 mL/kg with an inspiratory pause of 2.0 seconds.

*Suppliers are identified in the Product Sources section at the end of the text.

Abbreviations Used in this Paper

ACV	Assist-control ventilation
Ch_{dyn}	Dynamic characteristic
C_{FS}	Effective static compliance
CPAP	Continuous positive airway pressure
EEP	End-expiratory pressure
f	Respiratory frequency
IMV	Intermittent mandatory ventilation
MIP	Maximal inspiratory pressure (also $P_{I_{max}}$)
P_{aCO_2}	Arterial carbon dioxide tension
P_{aw}	Airway pressure
P_{aw}	Mean airway pressure
PEEP	Positive end-expiratory pressure
P_{etCO_2}	End-tidal carbon dioxide tension
PIP	Peak inspiratory pressure
$P_{plateau}$	Pressure at the end of airway occlusion or inspiratory pause, plateau pressure
$P_{I_{max}}$	Maximal inspiratory pressure (also MIP)
PSV	Pressure support ventilation
PSV_{max}	Maximum pressure support ventilation
$P_{0.1}$	Mouth occlusion pressure during the first 100 ms of inspiration against an occluded airway
S_{pO_2}	Oxygen saturation measured by pulse oximeter
T_I	Inspiratory time
V_D/V_T	Dead-space-to-tidal-volume ratio
$\dot{V}_E$	Minute ventilation
$\dot{V}_{CO_2}$	Carbon dioxide production
$\dot{V}_{O_2}$	Oxygen consumption
V_T	Tidal volume
$\dot{V}_{vent}$	Ventilator-set inspiratory flowrate

A Guide to the Use of SI in This Paper*

The SI unit for pressure is the kilopascal (kPa).
(cm H_2O)(0.098 06) = kPa
(torr)(0.133 3) = kPa.

The SI unit for compliance is mL/kPa.
(mL/cm H_2O)(10.20) = mL/kPa.

*For further information on SI (le Systeme International d'Unites), see Respir Care 1988;33:861-873 (October 1988) and Respir Care 1989;34:145 (February 1989 Correction).

Recordings of peak inspiratory pressure (PIP), plateau pressure ($P_{plateau}$), and end-expiratory pressure (EEP) were made with a standard physiologic pressure transducer at the proximal end of the endotracheal

Table 1. Description of the 15 Patients Studied

Patient No.	Age/ Sex	Duration of Ventilation (days)	Diagnosis
1	19 F	34	ARDS, sepsis, viral pneumonia
2	63 F	16	COPD, perforated duodenal ulcer
3	71 M	10	COPD, pneumonia
4	52 M	18	COPD, perforated gastric ulcer
5	66 F	15	Kyphoscoliosis, pneumonia
6	34 M	22	Multiple trauma, ARDS
7	50 M	12	Pancreatitis, malnutrition
8	49 M	15	CABG, pneumonia
9	38 M	23	Pancreatitis, ARDS
10	26 M	9	Pulmonary contusion, ruptured diaphragm, flail chest
11	83 M	7	Fractured hip, pneumonia
12	57 M	17	Ruptured aneurysm of abdominal aorta
13	79 F	8	Fractured sternum, pulmonary contusion
14	29 M	22	Pancreatitis, ARDS
15	41 M	14	Liver laceration, ARDS
mean (SD)	50 (18)	16.1 (7)	

ARDS = adult respiratory distress syndrome.
CABG = coronary artery bypass grafting.
COPD = chronic obstructive pulmonary disease.

tube. We used volume measurements from the IRISA to calculate Ch_{dyn} and C_{ES}. Because the reported volumes are not corrected for compressible volume, some error in the measurement is present. However, we performed all measurements with the same technique and any error should thus be systematic. The measurements of Ch_{dyn} and C_{ES} were used only as indicators of the severity of the patient's lung disease, and were not used to monitor patient response to ventilator manipulations. All patients were ventilated at PSV_{max} as described by MacIntyre[1] (that is, PSV was set to deliver a V_T of 10-12 mL/kg and to maintain respiratory frequency [f] $\leq$ 20 breaths/min). The same IRISA ventilator was used throughout the study.

The IRISA ventilator is a microprocessor-controlled ventilator capable of delivering PSV at up to 80 cm H_2O [7.8 kPa]. Inspiration is initiated when the patient's spontaneous inspiratory effort causes a change in circuit pressure. Although the IRISA is essentially pressure-triggered, a more sophisticated scheme is used prior to delivery of a PSV breath. Upon patient inspiration, the demand valve opens as during conventional intermittent mandatory ventilation (IMV). When at least 25 mL of gas has exited the demand system at a minimum flow of 1.5 L/min for 50 ms, the PSV breath is delivered.[3] This sequence is intended to provide a minimum sensitivity (preset at -0.7 cm H_2O [0.07 kPa]) while avoiding autocycling caused by leaks in the ventilator circuit or around the endotracheal or tracheostomy tube.

Patients were initially ventilated using the maximum flowrate (fastest rise to peak pressure) for 1 hour. During this time, V_T and minute ventilation ($\dot{V}_E$) were continuously monitored by the ventilator's integral volume transducer. Airway pressures were continuously monitored at the patient's airway and recorded on a strip-chart recorder. PIP, mean airway pressure ($\bar{P}_{aw}$), and EEP were recorded. Respiratory rate (f) and inspiratory time (T_I) were determined from the strip-chart recordings of airway pressure (P_{aw}). Oxygen consumption ($\dot{V}_{O_2}$) and carbon dioxide production ($\dot{V}_{CO_2}$) were monitored continuously by indirect calorimetry. Expired gases were collected into the calorimeter for the last 5 min of the 1-hour period for determination of the dead-space-to-tidal-volume ratio (V_D/V_T). Arterial blood was sampled from indwelling catheters for measurement of blood gas and pH values. Samples were run immediately following sampling and reported at patient body temperature. End-tidal carbon dioxide (P_{etCO_2}) and oxygen saturation (S_{pO_2}) were monitored by calorimeter and pulse oximeter throughout the study, and heart rate and blood pressure were continuously monitored according to standard ICU policy. After measurements were completed, the flowrate was decreased to the minimum flow necessary to achieve the desired level of PSV. This was done by decreasing

flow until the pressure fell below the desired level and then increasing it slowly until set PSV was reached. Following 1 hour at the minimum flowrate, measurements were repeated. Flow was then adjusted to produce an airway pressure waveform with a moderate rise to peak pressure and a smooth transition to the plateau. This flow was always less than maximum flow and greater than minimum flow. Measurements were performed after 1 hour at this setting. Patients were suctioned as needed during the study. Medical management (eg, fluids and nutrition) was kept constant during the study period.

Statistical analysis was performed with commercially available software. Analysis of variance for repeated measures was used to compare variables at the three different flowrates. A value of $p < 0.05$ was considered significant. Comparison of differences between groups was done by one-way ANOVA.

Table 2. Changes in Frequency and Tidal Volume Seen at Three Levels of Ventilator Flowrate

	High Flowrate	Midrange Flowrate	Low Flowrate
Group I (n = 4): lowest f and largest V_T at highest $\dot{V}_{vent}$			
$\dot{V}_{vent}$ (L/min)	107 (8)*	80 (18)	61 (13)
f (breaths/min)	15 (3.5)	18 (3	22) (9)†
V_T (L)	0.94 (0.2)†	0.86 (0.4)	0.80 (1.4)
$\dot{V}_E$ (L/min)	14.1 (3.3)	15.5 (2.7)	17.6 (3.8)†
T_I (s)	1.2 (0.27)	1.3 (0.34)	1.3 (0.33)
V_D/V_T	0.47 (0.04)	0.49 (0.06)	0.54 (0.06)‡
P_{aO_2} (torr)§	106 (27)	98 (21)	94 (23)
P_{aCO_2} (torr)	39 (3.5)	41 (3.1)	44 (2.7)
$\bar{P}_{aw}$ (cm H_2O)	8.9 (3.2)	9.4 (2.5)	9.6 (2.9)
$\dot{V}_{O_2}$ (L/min)	297 (42)	298 (45)	329 (38)†
HR (beats/min)	88 (12)	89 (10)	93 (16)
MAP (torr)‖	79 (15	84 (15	86 (18
Group II (n = 7): lowest f and largest V_T at midrange $\dot{V}_{vent}$			
$\dot{V}_{vent}$ (L/min)	108 (13)	77 (18)	54 (17)
f (breaths/min)	16 (2.4)	12 (1.6)	15 (2.8)
V_T (L)	0.75 (0.1)	0.85 (0.1)†	0.79 (0.1)
$\dot{V}_E$ (L/min)	12.4 (2.2)	10.2 (1.6)	12.1 (22)
T_I (s)	1.09 (0.22)	1.7 (0.23)‡	1.5 (0.24)
V_D/V_T	0.54 (0.05)	0.46 (0.06)†	0.51 (0.06)
P_{aO_2} (torr)	92 (24)	101 (29)	90 (18)
P_{aCO_2} (torr)	46 (10)	39 (2.9)‡	42 (2.5)
Group II *continued*			
$\bar{P}_{aw}$ (cm H_2O)	12.3 (3.4)	13.0 (2.8)	14.1 (3.1)
$\dot{V}_{O_2}$ (L/min)	301 (39)	295 (42)	310 (36)
HR (beats/min)	74 (11)	72 (15)	75 (15)
MAP (torr)	81 (17)	79 (14)	84 (13)
Group III (n = 4): lowest f and largest V_T at lowest $\dot{V}_{vent}$			
$\dot{V}_{vent}$ (L/min)	101 (14)	68 (20)	44 (9)
f (breaths/min)	14 (3.5)	13 (3)	11 (2.5)‡
V_T (L)	0.85 (0.16)	0.85 (0.12)	0.93 (0.16)†
$\dot{V}_E$ (L/min)	11.5 (2.3)	11.0 (1.2)	10.2 (1.4)
T_I (s)	1.2 (0.21)	1.42 (0.31)	2.1 (0.49)†
V_D/V_T	0.49 (0.11)	0.46 (0.08)	0.42 (0.07)‡
P_{aO_2} (torr)	97 (12)	106 (19)	110 (15)
P_{aCO_2} (torr)	44 (9)	43 (8.6)	42 (6.4)
$\bar{P}_{aw}$ (cm H_2O)	10.3 (2.2)	11.2 (1.9)	12.7 (1.6)
$\dot{V}_{O_2}$ (L/min)	309 (27)	306 (26)	305 (25)
HR (beats/min)	70 (12)	73 (16)	71 (12)
MAP (torr)	74 (18)	75 (15)	71 (16)

*All values are mean (SD).
†$p < 0.05$ compared to the other two flowrates.
‡$p < 0.05$ compared to the highest $\dot{V}_{vent}$.
§ See box for SI conversions.
‖ MAP = mean arterial pressure.

Results

The effect of varying flowrate during PSV differed from patient to patient. We placed patients into one of three groups based on their response to $\dot{V}_{vent}$. Group I (n = 4) had the lowest f and largest V_T at the highest flowrate. Group II (n = 7) had the lowest f and largest V_T at the midrange flowrate, and Group III (n = 4) had the lowest f and largest V_T at the slowest flowrate. Table 2 summarizes study results. The mean (SD) level of PSV applied was 18 (6) (range 15-30) cm H_2O [1.8 (0.6) (range 1.5-2.9) kPa].

In Group I, as $\dot{V}_{vent}$ was decreased V_T fell and f increased to maintain the desired $\dot{V}_E$. At the highest flowrate, V_T was significantly larger than at the other two flowrates ($p < 0.05$). As $\dot{V}_{vent}$ was decreased, V_D/V_T ($p < 0.05$) also increased as did $\dot{V}_E$ ($p < 0.05$) in order to maintain a normal P_{aCO_2}. One patient who initially had been entered into the study would not tolerate any reduction in flowrate below the maximum. This patient who was recovering from alcoholic pancreatitis had a $\dot{V}_E$ of 18 L/min. Because no comparisons could be made to the other two flowrates, his data were eliminated from analysis. Group I patients also demonstrated a significant increase in $\dot{V}_{O_2}$ at the lowest $\dot{V}_{vent}$ compared to the high and midrange $\dot{V}_{vent}$.

Patients in Group II had a larger V_T with a lower f and longer T_I during ventilation at the midrange $\dot{V}_{vent}$ compared to the other two flows. At the midrange flow, P_{aCO_2} also fell from mean (SD) of 46 (10) to 39 (3) torr [6.1 (1.3) to 5.2 (0.4) kPa], $p < 0.05$) compared to the highest flow. Group III patients had larger V_T, longer T_I, and decreased f at the lowest flow compared to the other two flowrates. The V_D/V_T was also lower at the lowest flow.

All patients (except the one intolerant to any change from maximum flowrate) completed the study without incident. Comparison of the three groups reveals that Group I patients had an overall higher $\dot{V}_E$ requirement and shorter T_I than Groups II and III (Table 3). The minimum flow to maintain pressure support was also greater in Group I than in Groups II and III (61 [13] L/min compared to 54 [17] and 44 [9] L/min). Mean age in Group II was higher than in Groups I and III. Both Ch_{dyn} and C_{ES} were lowest in Group I and highest in Group III. Group III demonstrated larger differences between Ch_{dyn} and C_{ES}, suggesting a greater component of airway resistance in this group. Duration of ventilation prior to the study was significantly less in Group II than in either Group I or III. No statistically significant differences were seen in heart rate or mean arterial blood pressure in any patient during manipulation of $\dot{V}_{vent}$.

Table 3. Comparisons Among Subjects Grouped According to Response to Flowrate Variation

	Group I*	Group II	Group III
Age (years)	42 (17)†	58 (22)‡	45 (19)
Duration of ventilation prior to study (days)	20 (4)	11 (3.5)‡	21 (9)
Ch_{dyn} (mL/cm H_2O)§	31 (12)‖	38 (11)	40 (10)
C_{ES} (mL/cm H_2O)	35 (9)	40 (12)	46 (14)‡
$\dot{V}_E$ at optimum $\dot{V}_{vent}$ (lowest f, largest V_T, L/min)	14.1 (3.3)‡	10.2 (1.6)	10.2 (1.4)
Longest T_I (regardless of $\dot{V}_{vent}$, s)	1.3 (0.34)	1.7 (0.73)	2.1 (0.49)†
Minimum $\dot{V}_{vent}$ at which PSV maintained	61 (13)	54 (17)	44 (9)

*Group I = lowest f, largest V_T at maximum $\dot{V}_{vent}$.
Group II = lowest f, largest V_T at midrange $\dot{V}_{vent}$.
Group III = lowest f, largest V_T at lowest $\dot{V}_{vent}$.
†Values are mean (SD).
‡$p < 0.05$ compared to other two groups.
§See box for SI conversions.
‖$p < 0.05$ compared to Group III.

Discussion

Pressure support ventilation has been reported to reduce ventilatory work load, prevent diaphragmatic fatigue, compensate for additional work of breathing caused by poorly functioning demand valves and undersized endotracheal tubes, improve patient-ventilator synchrony, and facilitate weaning.[1,2,4-8] Perhaps chief among these benefits is improved patient-ventilator synchrony. Each of the reports just referenced have described improved patient comfort during PSV compared to either intermittent mandatory ventilation (IMV), assist-control ventila-

tion (ACV), or continuous positive airway pressure (CPAP). Patient-ventilator synchrony and its importance during mechanical ventilation have only recently been appreciated. Early studies were generally related to triggering the ventilator in ACV or the demand valve during IMV.[9-13] If the patient is unable to trigger the ventilator or if excessive work is required to initiate flow—dysynchrony, increased work of breathing, and intolerance to the ventilator mode can result. In fact, early adverse experiences with IMV have been attributed to improperly functioning equipment resulting in patient intolerance.[14] Marini et al demonstrated that patient work during ACV is not only affected by triggering pressure but also by ventilator flow setting.[15] More specifically, when patient demand for flow is in excess of the set $\dot{V}_{vent}$, the patient may continue to perform work throughout inspiration equal to that of unassisted breathing.[15,16] Thus, matching set $\dot{V}_{vent}$ to patient demand during ACV is important to attaining the goals of reducing the work of breathing and improving synchrony.[17]

During PSV, $\dot{V}_{vent}$ is normally not clinician set.[2] Once the pressure-supported breath is triggered, the ventilator provides sufficient flow to quickly reach and maintain the desired pressure. This allows patient control over ventilatory timing and volume. Although this rapid rise to pressure seems to be an important mechanism by which PSV can improve patient comfort and synchrony, adjustment of $\dot{V}_{vent}$ during PSV may be valuable.

Czervinske et al[18] were the first to describe altering $\dot{V}_{vent}$ during PSV. While ventilating infants in the PSV mode with the Siemens 900C, they noted that inspiration appeared to terminate prematurely. They attributed this to the high $\dot{V}_{vent}$ delivered by the 900C ($>$ 90 L/min) coupled with the relatively small endotracheal tubes (3.0 mm-4.0 mm ID) required for their patient population. Because it was not feasible to employ larger endotracheal tubes, they elected to alter $\dot{V}_{vent}$ by reducing working pressure on the 900C to a level 5-10 cm H_2O [0.5-1.0 kPa] above the desired level of PSV. Following this manipulation, Czervinske and colleagues found that T_I and V_T increased while f fell. Consequently, premature termination of the PSV breath was avoided. Durham and co-workers have shown similar results in adults using the 900C.[19] Iotti et al[20] used a modified Hamilton Veolar to investigate the effects of variable $\dot{V}_{vent}$ during PSV. Performing 24 trials on 5 patients, they varied $\dot{V}_{vent}$ from 64 to 73 L/min and finally to 79 L/min while continuously monitoring ventilatory timing. They found that at the highest $\dot{V}_{vent}$, T_I was shortened and f slightly increased. By measuring flow continuously, they calculated the flow at which inspiration was terminated for $\dot{V}_{vent}$ at 18.6, 22.8, and 27 L/min, respectively. They concluded that the higher $\dot{V}_{vent}$ leads to premature termination of inspiration, causing the patient to breathe more frequently to maintain the desired $\dot{V}_E$. Although the Veolar is said to terminate inspiration at 25% of peak flow, the data from Iotti et al[20] show that termination occurred at 28, 31, and 34%, respectively. This suggests either that termination of inspiration varies due to higher flowrates or that the ability of the ventilator to sense when inspiration should end is affected by high $\dot{V}_{vent}$. Analysis of our data suggests that the IRISA terminates inspiration between 26 and 30% of $\dot{V}_{vent}$ regardless of the level of $\dot{V}_{vent}$. We believe this to be acceptable, given current ventilator technology.

More recently, Ho and MacIntyre[21] have reported on the effects of a variable $\dot{V}_{vent}$ during PSV with the IRISA ventilator. Their study used only the maximum mean [SD] (102 [24] L/min) and minimum (39 [8] L/min) $\dot{V}_{vent}$ available from the IRISA. When the data were compiled and viewed as a whole, only the PSV level was significantly different (23 vs 16 cm H_2O [2.3 vs 1.6 kPa]). However, Ho and MacIntyre did demonstrate significant changes in V_T, T_I, and f when patients were separated into two groups—those who had the largest V_T at low $\dot{V}_{vent}$ and those who had the largest V_T at high $\dot{V}_{vent}$. They concluded that variable $\dot{V}_{vent}$ during PSV is a valuable characteristic of a PSV system that can assist in optimizing patient-ventilator synchrony.

Our results are similar to those of the studies just described. Although it may appear that during PSV, as with ACV, a high $\dot{V}_{vent}$ in excess of patient demand is desirable, an important difference exists. During AMV, if $\dot{V}_{vent}$ is in excess of patient demand, the work of breathing is minimal.[15-17] But, ACV is a volume-oriented mode that guarantees delivery of the set V_T. During PSV, excess $\dot{V}_{vent}$ may help reduce the work of breathing during the initial phase of inspiration, but if inspiration is prematurely terminated, it may increase the work of breathing during the last portion of inspiration. This occurs when the patient continues to require flow after the

ventilator has cycled into the expiratory phase. Diminution of V_T and shortening of T_I accompanies this phenomenon.

This principle is easily explained mathematically. If patient demand is 60 L/min and termination of inspiration occurs at 25% of peak flow, then when patient demand falls below 15 L/min, inspiration will end. When $\dot{V}_{vent}$ exceeds patient demand (ie, ventilator flow is 90 L/min), then inspiration is terminated at 22.5 L/min of patient demand. This corresponds to an inspiratory termination at 37.5% of actual flow required by the patient. Figure 1 depicts the airway

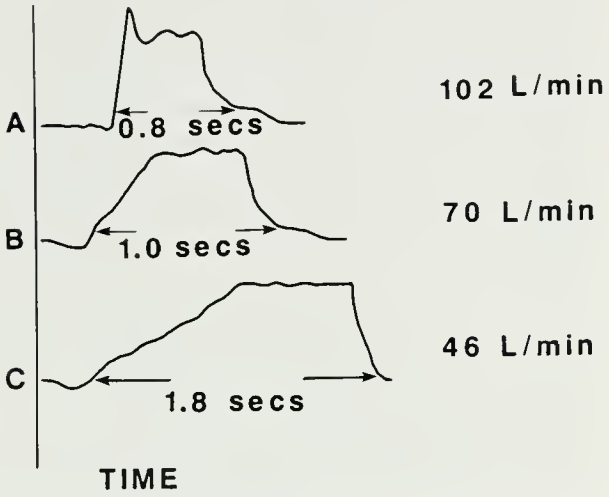

Fig. 1. Effect of changing $\dot{V}_{vent}$ in a patient preferring a slow flow. In A, flowrate is in excess of patient demand, causing the characteristic pressure spike above the set PSV level. In B, as flowrate is decreased, T_I lengthens and the transition to set PSV is smooth. As flowrate is further reduced, T_I continues to increase. In this patient (No. 1), the slowest $\dot{V}_{vent}$, resulted in the lowest f and the largest V_T.

pressure waveforms created as $\dot{V}_{vent}$ is manipulated. At A, the ventilator $\dot{V}_{vent}$ is in excess of patient demand resulting in the characteristic overshoot of set PSV and subsequent 'ringing' at the pressure plateau. At this $\dot{V}_{vent}$, T_I is 0.8 s, V_T is 0.72 L, and f is 18 breaths/min. In B, ventilator $\dot{V}_{vent}$ is reduced to 70 L/min, T_I is 1.0 s, V_T is 0.75 L, and f is 16 breaths/min. As $\dot{V}_{vent}$ is reduced to 46 L/min in C, T_I is 1.8 s, V_T is 0.84 L, and f is 13 breaths/min. This is characteristic of the changes seen in Group III. Our results also suggest that in this group as $\dot{V}_{vent}$ is reduced and T_I lengthens, VD/V_T may decrease. This may be (1) the result of improved distribution of gases with a longer T_I, (2) simply because a large V_T is delivered, or (3) a combination of both. This group of patients also demonstrated a greater difference in Ch_{dyn} and C_{ES} suggesting that airway resistance was more of a factor in their disease process. Whether this plays a role in their response to a lower $\dot{V}_{vent}$ is uncertain.

In Group I, we found that changing $\dot{V}_{vent}$ was less useful. These patients demonstrated a slightly longer T_I as $\dot{V}_{vent}$ was decreased, but V_T fell and f increased. We believe that the response of this group approximates the findings of Marini et al[15] in patients on ACV. Marini et al found that as $\dot{V}_{vent}$ was reduced below patient demand, patients became uncomfortable and tachypneic. At the lowest $\dot{V}_{vent}$ capable of maintaining set PSV, $\dot{V}_{O_2}$ also increased—suggesting patient discomfort and an increase in the work of breathing. The minimum $\dot{V}_{vent}$ required to maintain PSV was significantly higher in this group than in Group III with mean (SD) of 61 (13) vs 44 (9) L/min. These findings are similar to those of Ho and MacIntyre[21] who demonstrated that patients with a higher ventilatory demand as characterized by a higher $\dot{V}_E$ and shorter T_I preferred a higher $\dot{V}_{vent}$. In retrospect, had we measured the pressure during the first 100 ms of inspiration against an occluded airway ($P_{0.1}$) we might have had a more precise indication of ventilatory drive.[22] Nevertheless, our results agree with those of Ho and MacIntyre. Group III patients also had a lower mean C_{ES} compared to Group I patients, which also suggests the need for a higher $\dot{V}_{vent}$. Figure 2 depicts typical pressure waveforms seen in this group. In A, set PSV is reached quickly and the spike seen in Group I patients is absent. As $\dot{V}_{vent}$ is decreased (B), T_I increases only slightly and when $\dot{V}_{vent}$ is at its minimal setting (C), the pressure waveform is distorted as patient demand exceeds ventilator supply. The characteristic patient response to this is a decrease in V_T, an increase in f and $\dot{V}_E$, and patient discomfort and dysynchrony. Not surprisingly, the majority of patients studied preferred a moderate $\dot{V}_{vent}$. In those patients, $\dot{V}_{vent}$ in excess of patient demand caused premature termination of inspiration, short T_I, and decreased V_T; $\dot{V}_{vent}$ less than patient demand caused a fall in V_T, a rise in f, and patient discomfort. Figure 3 depicts typical pressure waveforms for this group. In A, $\dot{V}_{vent}$ is in excess of patient demand and the characteristic

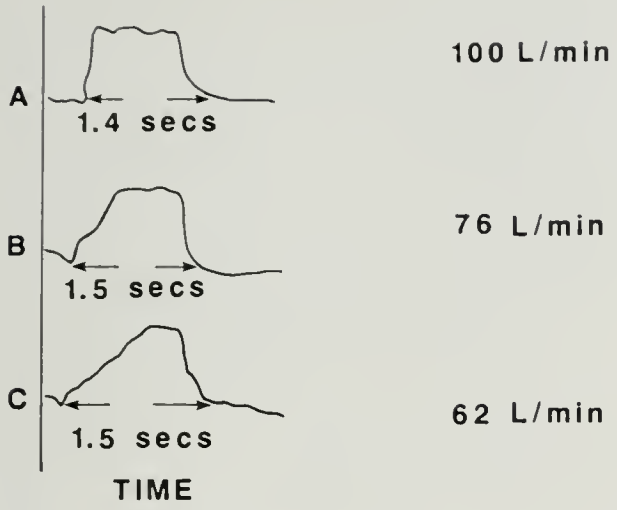

Fig 2. Effect of changing $\dot{V}_{vent}$ in a patient preferring a high flow. In A, the highest $\dot{V}_{vent}$ produces a rapid rise to set PSV level and smooth transition to the pressure plateau. Note the absence of the pressure spike. As flowrate is decreased (B and C), the time to reach the PSV level is lengthened and T_I increases slightly. Deformation of the pressure waveform prior to reaching the set PSV level may represent patient demand in excess of set flow.

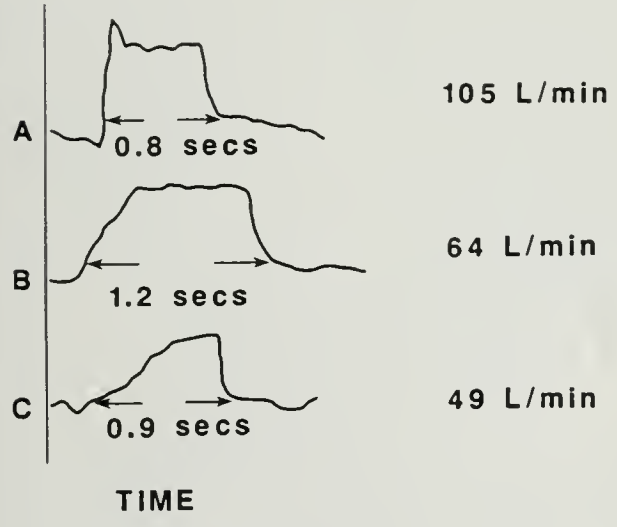

Fig. 3. Effect of changing $\dot{V}_{vent}$ in a patient preferring a midrange flow. In A, flow is in excess of patient demand and the pressure spike is seen. As flowrate is decreased (B), T_I lengthens and the pressure spike is absent—machine output matches patient demand. When flowrate is further reduced (C), patient demand exceeds machine flowrate and T_I falls. Deformation of the pressure waveform during the rise to the set PSV level is also seen in C.

spike is present. As $\dot{V}_{vent}$ closely matches patient demand in B, the waveform becomes smoother and T_I and V_T increase. If $\dot{V}_{vent}$ falls below patient demand, then the waveform becomes distorted (C) and patient-ventilator synchrony is compromised. Patients in Group II had $\dot{V}_E$ requirements, Ch_{dyn}, C_{ES}, and mean T_I between those of Groups I and III (Table 3).

We did not measure the work of breathing during our study. Messadi and colleagues[22] recently compared the work of breathing during PSV with a "fast $\dot{V}_{vent}$" vs a "slow $\dot{V}_{vent}$." They used a modified Hamilton Veolar to study nine patients at 15-cm H_2O PSV. They saw no changes in arterial blood gas values or breathing pattern, but patient work of breathing was significantly greater during PSV with a slow $\dot{V}_{vent}$ (0.33 vs 0.59 J/L). Because we chose minimum f and largest V_T to determine optimum $\dot{V}_{vent}$, and because $\dot{V}_{O_2}$ was unchanged, we do not suspect that work of breathing is always increased as $\dot{V}_{vent}$ is decreased. However, in Group I patients, we believe decreasing $\dot{V}_{vent}$ well below patient demand may have adversely affected patient work.

Conclusion

We conclude that the ability to adjust inspiratory flow during PSV is useful for tailoring ventilator flow to patient demand and can result in improved patient-ventilator synchrony. Optimum $\dot{V}_{vent}$ can be provided by monitoring f, V_T, and T_I. Observation of the airway pressure waveform is also helpful and may facilitate the setting of an appropriate $\dot{V}_{vent}$. Patients with higher ventilatory drive and lower lung compliance appear to prefer a higher $\dot{V}_{vent}$; whereas those with lower drive and increased airway resistance prefer a lower $\dot{V}_{vent}$. We believe that more precise indices of ventilatory drive such as $P_{0.1}$ and maximal inspiratory pressure (MIP, or $P_{f_{max}}$) may prove useful in determining appropriate $\dot{V}_{vent}$, but this remains to be studied. We caution that these results were obtained while patients were ventilated at PSV_{max}; therefore, these results may not be applicable in situations in which PSV is used only to overcome the imposed work of breathing caused by endotracheal-tube resistance and/or poorly responsive demand valves. Future research in the design of PSV systems should address the issue of ventilator $\dot{V}_{vent}$ vs patient demand and, perhaps, modification of the inspiratory termination criteria. The optimum PSV breath may

be one with variable $\dot{V}_{vent}$ and variable termination of inspiration. Certainly, tailoring of the PSV breath to individual patient need is desirable.

PRODUCT SOURCES

Airway Pressure Monitor:
Bunnell Airway Pressure Monitor, Mallinckrodt Critical Care, Glen Falls NY

Indirect Calorimeter:
2900 System, SensorMedics Inc, Yorba Linda CA

Pulse Oximeter:
Nellcor N-200, Nellcor Inc, Hayward CA

Pressure Transducer:
Trantec Disposable Transducer, American Edwards Laboratories, Irvine CA

Recorder:
Gould TA 550, Gould Inc, Dayton OH

Ventilator:
Intelligent Respiratory Integrated System Advantage (IRISA), PPG BioMedical Systems, Lenexa KS

Statistical Software:
SPSS/PC+, SPSS Inc, Chicago IL

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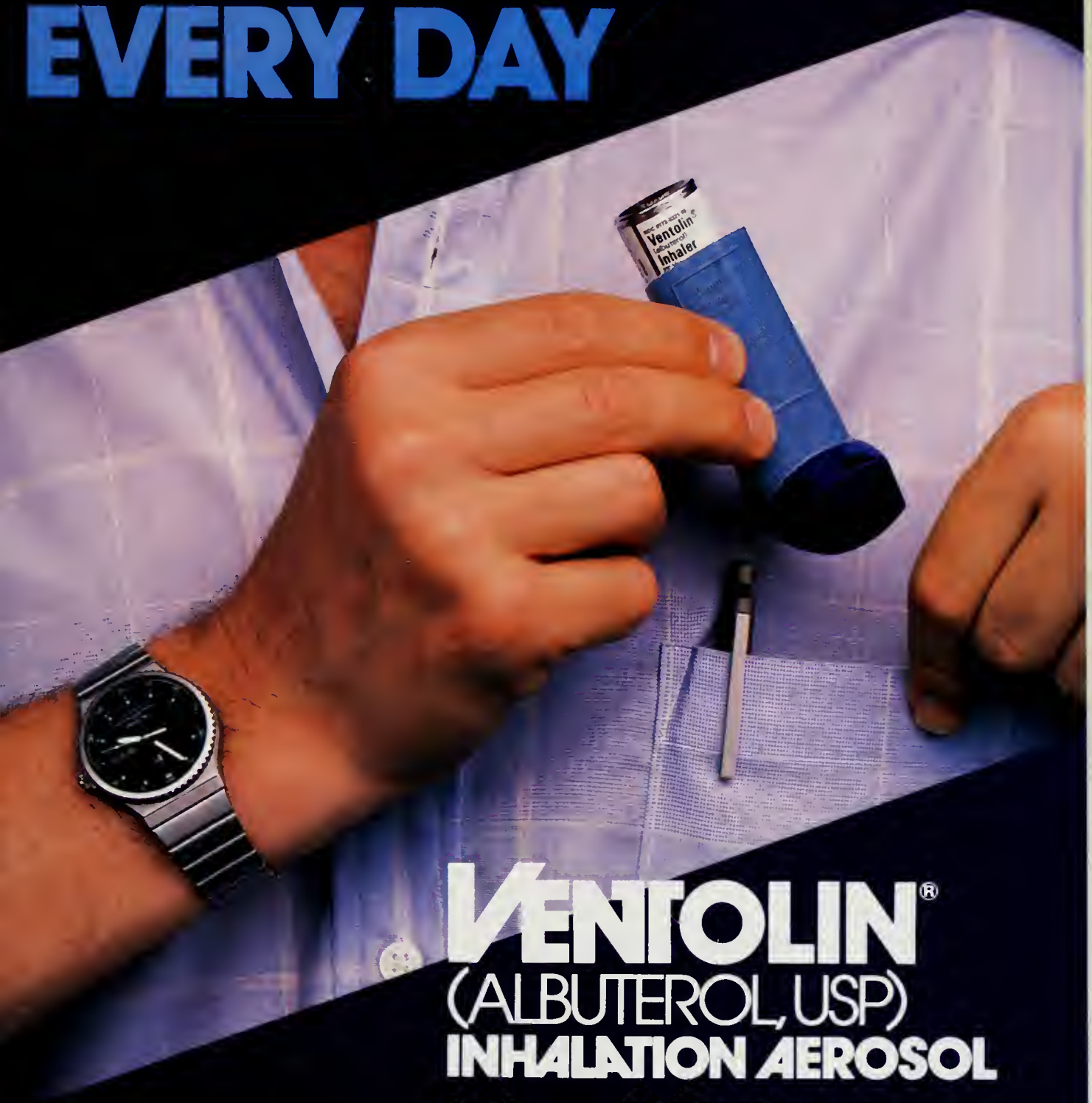

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BRIEF SUMMARY

Bronchodilator Aerosol
For Oral Inhalation Only

The following is a brief summary only. Before prescribing, see complete prescribing information in Ventolin® Inhalation Aerosol product labeling.

CONTRAINDICATIONS: Ventolin® Inhalation Aerosol is contraindicated in patients with a history of hypersensitivity to any of its components.

WARNINGS: As with other inhaled beta-adrenergic agonists, Ventolin® Inhalation Aerosol can produce paradoxical bronchospasm that can be life threatening. If it occurs, the preparation should be discontinued immediately and alternative therapy instituted.

Fatalities have been reported in association with excessive use of inhaled sympathomimetic drugs. The exact cause of death is unknown, but cardiac arrest following the unexpected development of a severe acute asthmatic crisis and subsequent hypoxia is suspected.

Immediate hypersensitivity reactions may occur after administration of albuterol inhalation aerosol, as demonstrated by rare cases of urticaria, angioedema, rash, bronchospasm, anaphylaxis, and oropharyngeal edema.

The contents of Ventolin Inhalation Aerosol are under pressure. Do not puncture. Do not use or store near heat or open flame. Exposure to temperatures above 120°F may cause bursting. Never throw container into fire or incinerator. Keep out of reach of children.

PRECAUTIONS:

General: Albuterol, as with all sympathomimetic amines, should be used with caution in patients with cardiovascular disorders, especially coronary insufficiency, cardiac arrhythmias, and hypertension, in patients with convulsive disorders, hyperthyroidism or diabetes mellitus, and in patients who are unusually responsive to sympathomimetic amines.

Large doses of intravenous albuterol have been reported to aggravate pre-existing diabetes mellitus and ketoacidosis. Additionally, beta-agonists, including albuterol, given intravenously may cause a decrease in serum potassium, possibly through intracellular shunting. The decrease is usually transient, not requiring supplementation. The relevance of these observations to the use of Ventolin® Inhalation Aerosol is unknown, since the aerosol dose is much lower than the doses given intravenously.

Although there have been no reports concerning the use of Ventolin Inhalation Aerosol during labor and delivery, it has been reported that high doses of albuterol administered intravenously inhibit uterine contractions. Although this effect is extremely unlikely as a consequence of aerosol use, it should be kept in mind.

Information For Patients: The action of Ventolin Inhalation Aerosol may last up to six hours, and therefore it should not be used more frequently than recommended. Do not increase the number or frequency of doses without medical consultation. If recommended dosage does not provide relief of symptoms or symptoms become worse, seek immediate medical attention. While taking Ventolin Inhalation Aerosol, other inhaled drugs should not be used unless prescribed.

See illustrated Patient's Instructions for Use section of the package insert.

Drug Interactions: Other sympathomimetic aerosol bronchodilators should not be used concomitantly with albuterol. If additional adrenergic drugs are to be administered by any route, they should be used with caution to avoid deleterious cardiovascular effects.

Albuterol should be administered with extreme caution to patients being treated with monoamine oxidase inhibitors or tricyclic antidepressants because the action of albuterol on the vascular system may be potentiated.

Beta-receptor blocking agents and albuterol inhibit the effect of each other.

Carcinogenesis, Mutagenesis, Impairment of Fertility: Albuterol sulfate, like other agents in its class, caused a significant dose-related increase in the incidence of benign leiomyomas of the mesovarium in a two-year study in the rat at doses corresponding to 111, 555, and 2,800 times the maximum human inhalational dose. In another study this effect was blocked by the coadministration of propranolol. The relevance of these findings to humans is not known. An 18-month study in mice and a lifetime study in hamsters revealed no evidence of tumorigenicity. Studies with albuterol revealed no evidence of mutagenesis. Reproduction studies in rats revealed no evidence of impaired fertility.

Pregnancy: ***Teratogenic Effects. Pregnancy Category C:*** Albuterol has been shown to be teratogenic in mice when given in doses corresponding to 14 times the human dose. There are no adequate and well-controlled studies in pregnant women. Albuterol should be used during pregnancy only if the potential benefit justifies the potential risk to the fetus. A reproduction study in CD-1 mice given albuterol subcutaneously (0.025, 0.25, and 2.5 mg/kg, corresponding to 1.4, 14, and 140 times the maximum human inhalational dose, respectively) showed cleft palate formation in 5 of 111 (4.5%) fetuses at 0.25 mg/kg and in 10 of 108 (9.3%) fetuses at 2.5 mg/kg. None was observed at 0.025 mg/kg. Cleft palate also occurred in 22 of 72 (30.5%) fetuses treated with 2.5 mg/kg isoproterenol (positive control). A reproduction study with oral albuterol in Stride Dutch rabbits revealed cranioschisis in 7 of 19 (37%) fetuses at 50 mg/kg, corresponding to 2,800 times the maximum human inhalational dose of albuterol.

Nursing Mothers: It is not known whether this drug is excreted in human milk. Because of the potential for tumorigenicity shown for albuterol in animal studies, a decision should be made whether to discontinue nursing or to discontinue the drug, taking into account the importance of the drug to the mother.

Pediatric Use: Safety and effectiveness in children below 12 years of age have not been established.

ADVERSE REACTIONS: The adverse reactions to albuterol are similar in nature to reactions to other sympathomimetic agents, although the incidence of certain cardiovascular effects is less with albuterol. A 13-week, double-blind study compared albuterol and isoproterenol aerosols in 147 asthmatic patients. The results of this study showed that the incidence of cardiovascular effects was: palpitations, less than 10 per 100 with albuterol and less than 15 per 100 with isoproterenol; tachycardia, 10 per 100 with both albuterol and isoproterenol; and increased blood pressure, less than 5 per 100 with both albuterol and isoproterenol. In the same study, both drugs caused tremor or nausea in less than 15 patients per 100, and dizziness or heartburn in less than 5 per 100 patients. Nervousness occurred in less than 10 per 100 patients receiving albuterol and in less than 15 per 100 patients receiving isoproterenol.

Rare cases of urticaria, angioedema, rash, bronchospasm, and oropharyngeal edema have been reported after the use of inhaled albuterol.

In addition, albuterol, like other sympathomimetic agents, can cause adverse reactions such as hypertension, angina, vomiting, vertigo, central nervous system stimulation, insomnia, headache, unusual taste, and drying or irritation of the oropharynx.

OVERDOSAGE: Information concerning possible overdosage and its treatment appears in the full prescribing information.

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RB2-219
May 1990

PFT Corner #39— Pulmonary Consequence of I.V. Drug Use

Joseph E Ollivier RRT and Peter Baylor MD

A 54-year-old man was referred to our clinic for persistent dyspnea upon exertion that had become progressively worse over the past year. The patient had a 40-pack-year history of smoking and a 15-year history of intravenous (I.V.) drug abuse. The physical examination was normal except for multiple skin tracts from drug injections. The chest radiograph revealed bilateral upper-zone nodular opacifications (Fig. 1). Resting (room air) arterial blood gas and pH values were normal. Pulmonary function testing was performed and the results are shown in Table 1.

Questions

1. How would you interpret the pulmonary function data shown in Table 1?
2. What may be the cause(s) of the pulmonary function impairment observed in this patient?
3. What further diagnostic testing may be indicated?

Mr Ollivier is a Senior Respiratory Therapist, and Dr Baylor is Associate Chief of the Pulmonary Section—Veterans Administration Medical Center, Fresno, California.

Table 1. Results of Pulmonary Function Tests of a 54-year-old Man with a 40-Pack-Year History of Smoking and a 15-Year History of I.V. Drug Abuse

Variable	(Units)	Actual	Predicted	% Predicted
FVC	(L)	4.21	4.86	87
FEV_1	(L)	2.66	3.85	69
FEV_1/FVC		63	79	
$FEF_{25-75\%}$	(L/s)	1.62	3.71	44
FIVC	(L)	4.28		
$FIF_{50\%}$	(L/s)	4.08	4.88	84
$FIF_{75\%}$	(L/s)	3.17	4.40	72
FIF_{max}	(L/s)	4.12	3.92	
TLC	(L)	6.85	6.74	102
FRC	(L)	6.85	6.74	102
RV	(L)	3.50	2.27	154
RV/TLC		51	34	
D_{LCO-sb}	(mL/min/torr)	8.30	29.81	28
$D_{LCO-sb-corrected}$*	(mL/min/torr)	8.21	29.81	28
Alveolar volume (VA)	(L)	6.47	6.82	95
D_{LCO}/VA		1.27	4.43	29

*$D_{LCO-sb-corrected}$ has had the hemoglobin correction factor applied.

Answers and Discussion on Next Page

Fig. 1. Chest radiograph of a 54-year-old man with 40-pack-year history of smoking and a 15-year history of I.V. drug abuse.

Answers

1. Interpretation of PFTs: FEV_1, FEV_1/FVC, and $FEF_{25-75\%}$ are reduced; the inspiratory flowrates are within normal limits; and FRC, RC, and RV/TLC are increased. The spirometry suggests mild obstructive airways disease.[1] The reduced D_{LCO} indicates a severe loss of functional alveolocapillary surface area.

2. Causes of PFT Impairment: The mild airway obstruction can probably be attributed to the patient's smoking history. Possible causes of a diffusion defect include severe anemia, emphysema, pulmonary fibrosis, and pulmonary vasculitis.[2] Because D_{LCO} was reduced despite correction for the patient's hemoglobin,[3] anemia can be ruled out. Emphysema can also be ruled out because it is unlikely that the mild degree of airflow obstruction seen in this patient would result in the severe loss of alveolar surface area suggested by this low D_{LCO}. Pulmonary fibrosis (of which there are many causes) is usually accompanied by a restrictive defect; because no radiographic or pulmonary function test evidence of restriction is seen in this patient, it is unlikely that pulmonary fibrosis is the cause of the low D_{LCO}. The pulmonary complications of repeated I.V. drug abuse include pneumocystis pneumonia and talc granulomatosis (with associated vasculitis), both of which can result in low D_{LCO}.

3. Further Diagnostic Testing: A transbronchial lung biopsy is indicated to diagnose pneumocystis pneumonia, talc granulomatosis with vasculitis, or sarcoidosis—all of which can cause an isolated reduction in D_{LCO} and result in dyspnea upon exertion. A symptom-limited exercise test to document oxygen desaturation on exertion could also be helpful. Transbronchial biopsy was performed, and revealed talc granulomatosis with vasculitis. A symptom-limited exercise test was also performed, consisting of having the patient walk up one flight of stairs while being continuously monitored by pulse oximeter. Pre- and post-exercise data (with the patient breathing room air) were: pulse oximetry saturation (S_{pO_2}) 96 and 88%, respiratory rate

20 and 34 breaths/min, and blood pressure 140/84 and 165/90 torr. (The patient has refused exercise evaluation using a metabolic measurement system and a cycle ergometer.)

Discussion

Talc (magnesium silicate) is known to be a filler in a number of medications used by I.V. drug users (eg, methadone tablets, pentazopine, and heroin). Its ability to create foreign body embolization to the lungs has been documented.[4] In addition to obstructing arterioles and capillaries, talc particles form granulomas, and cause thrombosis, vasculitis, interstitial fibrosis, and in some severe cases hypertrophy and angiomatoid malformation of the pulmonary arteries and arterioles. The incidence of talc granulomatosis in drug abusers ranges from 15 to 80% upon autopsy, depending on the type of addiction.[4] Dyspnea is the predominant symptom. In advanced stages with the occurrence of pulmonary hypertension, symptoms associated with right-heart failure and exercise-induced syncope may be evident.[5] Pulmonary function studies usually reveal a decreased diffusing capacity even in the absence of other abnormalities. In advanced disease, when the interstitium is affected, a reduction in lung volumes may be evident.[6] Unexplained airway obstruction has been seen in a number of patients with this disease,[7] but in this instance our patient's smoking probably accounted for this defect.

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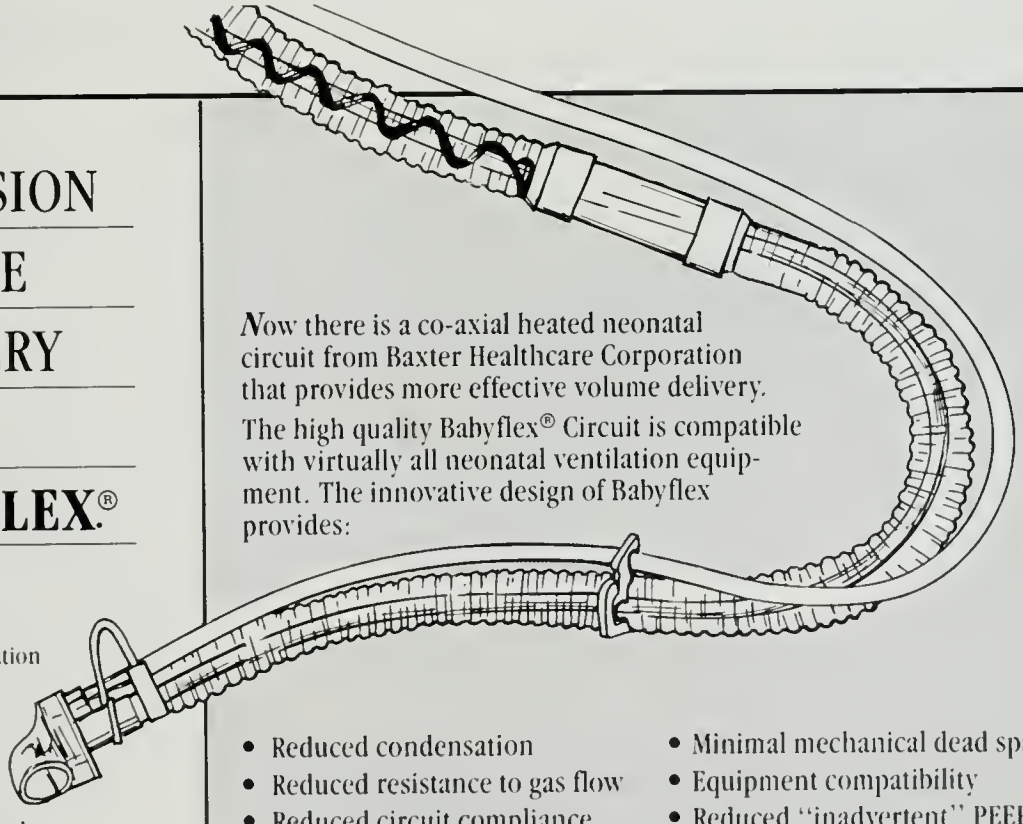

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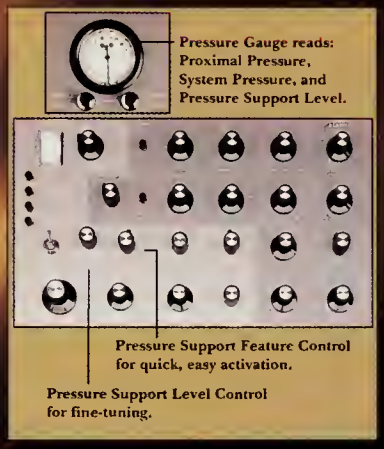
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Anatomic Variation of the Cardiopulmonary System

John M Palmisano RRT, Michele Bogaards MD, and Kimberly H Truman CVT

A 14-year-old boy with the diagnosis of pulmonary atresia and ventricular septal defect underwent an elective cardiac catheterization. The catheterization was performed to assess the boy's pulmonary artery anatomy and to determine whether a complete surgical repair, consisting of surgical closure of the ventricular septal defect and ligation of a large aortopulmonary collateral, could be undertaken at a future time. During a previous hospital admission (12 years prior to the catheterization), the child had undergone a palliative surgical repair consisting of a homograft between the right ventricle and the pulmonary artery.

Physical examination revealed the patient to be alert, cooperative, and in no distress. His weight was 30 kg, height 143 cm, heart rate 90 beats/min, respiratory rate 24 breaths/min, and upper-extremity blood pressure 110/62 torr while sitting.

Other pertinent findings included mild cyanosis (oxygen saturation by pulse oximetry was 92% with the subject at rest and breathing room air) and clubbing of the digits. Auscultation of the heart revealed an increased xiphoid impulse with a normal S_1 and a split S_2. A Grade III/VI harsh systolic ejection-murmur at the left upper sternal border was noted, and a Grade III/VI continuous murmur was heard over the entire chest. The lungs were clear to auscultation, and the edge of the liver was palpable 2 cm below the right costal margin.

The chest radiograph obtained during cardiac catheterization (Fig. 1) revealed normal pulmonary vasculature, mild cardiomegaly, and a right aortic arch. A two-dimensional echocardiogram and Doppler study showed trivial pulmonary and tricuspid regurgitation. The electrocardiogram was notable for right axis deviation and biventricular hypertrophy.

Fig. 1. Chest radiograph of a 14-year-old boy, obtained during a cardiac catheterization procedure. A pulmonary artery catheter is seen close to the left pulmonary artery.

Questions

Anatomic Variation: What anatomic variation can be seen in the chest radiograph obtained during cardiac catheterization?

Intubation Concerns: What concerns might you have prior to endotracheally intubating this subject?

Answers and Discussion on Next Page

The authors are staff personnel in the Pediatric Cardiac Catheterization Laboratory at CS Mott Children's Hospital, University of Michigan Medical Center, Ann Arbor, Michigan.

Answers

Anatomic Variation: A digitally-subtracted version* of the chest radiograph obtained during cardiac catheterization (Fig. 2) reveals an anomalous

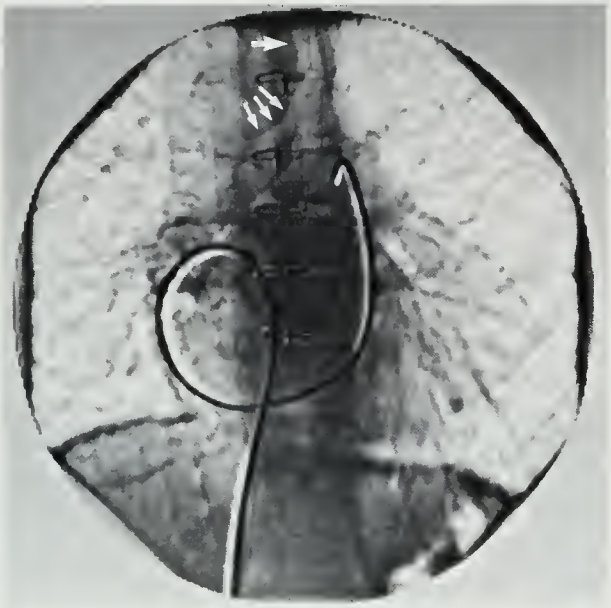

Fig. 2. A digitally-subtracted version of the chest radiograph shown in Figure 1—that of a 14-year-old boy, obtained during a cardiac catheterization procedure. Single arrow identifies the indentation and leftward shift of the trachea. Multiple arrows identify the displaced tracheal bronchus going to the right upper lobe.

bronchus arising from the trachea. This rare anomaly of the trachea is referred to as a "tracheal" or "pig" bronchus. A tracheal bronchus characteristically arises from the right side of the trachea, approximately 2 cm proximal to the carina, and may supply either the entire right upper lobe of the lung or the apical segment of the right upper lobe.

Another anatomic variation visible in the chest radiograph is a right-sided aortic arch. This is readily identified by the indentation and leftward shift of the trachea from its normal midline position. A right aortic arch is strongly associated with conotruncal malformations of the heart, most commonly tetralogy of Fallot and truncus arteriosus.

Intubation Concerns: Anatomic variation of the airway may pose significant problems during endotracheal intubation. In this particular situation, the primary concern is atelectasis or collapse of a lobe or lung segment; either may result from the obstruction of the tracheal bronchus by the endotracheal tube or cuff. There is also the danger of inadvertent intubation of the tracheal bronchus, which could result in overdistention of the respective lobe or segment of the lung and ultimately lead to a pneumothorax.[1]

Discussion

Usually the tracheal bronchus is an incidental finding during bronchoscopy. In a study of 412 children undergoing bronchoscopy for the evaluation of stridor and recurrent pneumonia, a tracheal bronchus was identified in 8 children (2%).[2] Occasionally, the patient with a tracheal bronchus may have related symptoms such as recurrent right-upper-lobe pneumonia. The presence of a tracheal bronchus may also be associated with other anomalous conditions such as asplenism, abnormal lobation, and congenital heart disease.[3]

The respiratory tract originates from the anterior division of the embryonic foregut at about 4 weeks of gestation.[4] The tracheobronchial diverticulum originates in the pharynx and divides into the two major bronchial branches that subsequently form the segmental bronchi, bronchioles, terminal bronchioles, and alveoli.[5] A tracheal bronchus 'bud' is present in utero, but in humans it usually resorbs; failure of this bud to regress may result in the formation of a tracheal bronchus. A study of comparative anatomy reveals that in swine, cattle, sheep, goats, camels, and giraffes, the bronchus that supplies the right upper lobe normally arises from the trachea.[6,7]

There are two distinct types of tracheal bronchus—"supernumerary" and "displaced." The supernumerary bronchus is comparatively rare, and is defined as a bronchus arising from the trachea in addition to those normally present. The displaced bronchus

*Digital subtraction angiography is the computer process of subtracting or eliminating unneccessary background information (eg, thoracic vetebrae, rib cage, lung fields) from the existing image; it can be used during the angiography procedure to enhance opacified vessels and to produce an image with greater detail, or it can be used to enhance an existing radiograph.

is more common, and is defined as one of the normally present bronchi abnormally placed.

In the absence of any clinical symptoms, a tracheal bronchus does not require intervention. However, in those patients with frequent right-upper-lobe infections, surgical resection of the anomalous bronchus is indicated.

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Instructions for Authors

In addition to case reports strictly involving pulmonary-medicine radiography, case reports involving adult, pediatric, and neonatal critical-care radiography can be submitted to the "Test Your Radiologic Skill" corner. However, all case reports should relate somehow to respiratory care. Illustrative radiographs may be of routine chest exams or of other less-common exams such as digital subtraction or computerized axial tomography.

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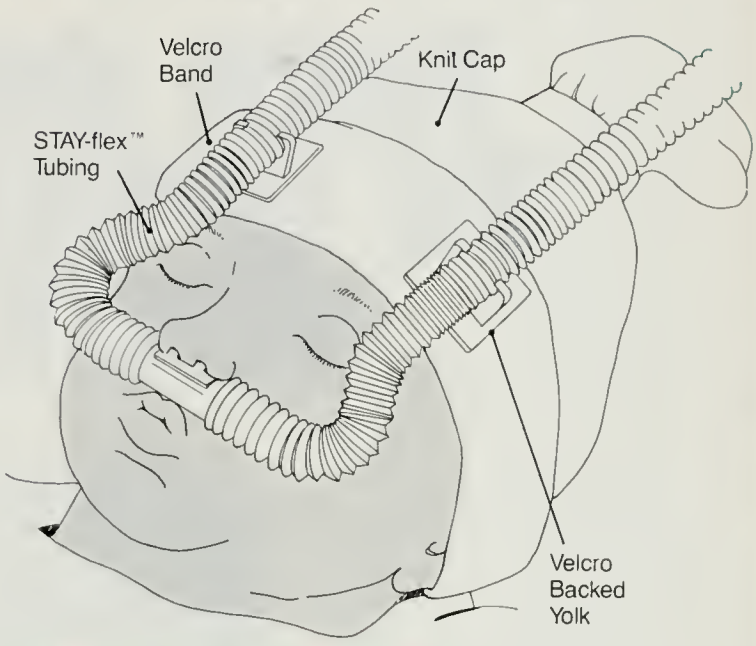

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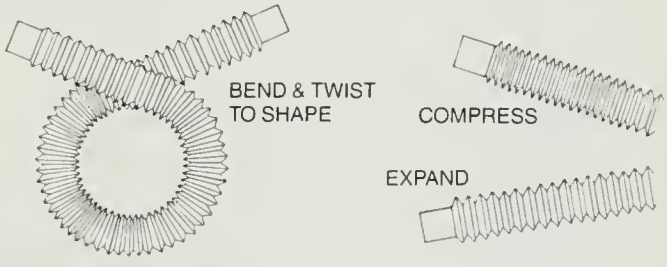

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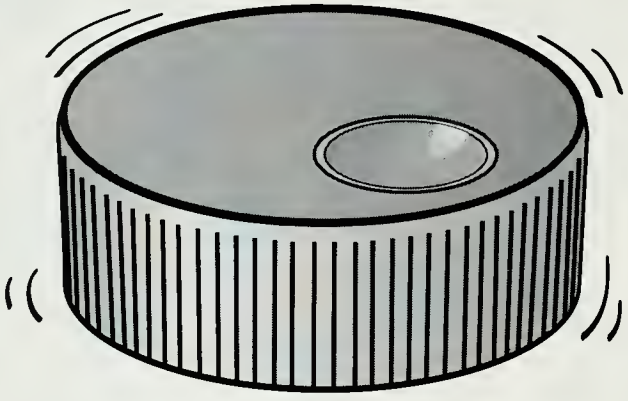

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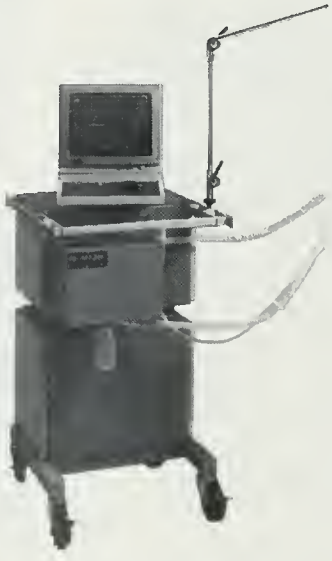

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". . . receive the fteam into the lungs . . ."

Rosemary F Young

It is the winter of 1750. One John Snat, saddler, of Old Bethlehem Gate, over against Moorfields, has trudged out to Tynburn Hill to catch what promised to be a particularly entertaining hanging.

He already had a cold, but then, so did practically everyone else in the crowd. Well, what with standing around in the half-frozen mud, and with the sleet driven clean through his coat by the wind, he had gone home with an ague, a fever, coughing, spitting—in short, the works. What to do?

Call the doctor? Certainly not! In all of London there are probably not more than 150 real physicians—which is far too few—and they charge a guinea a visit, for "advice" alone! Imagine!

The apothecary, then? There are at least a thousand of them—which is a good bit too many—and their advice is free. But oh, the number and nastiness of the prescriptions they will dump down their customers' throats—all without the advice of a physician—and all at a staggering cost.

Actually, a substantial part of medical practice in the 18th Century was carried on by the apothecaries, with no recourse to physicians at all. In fact, they had been licensed by the House of Lords in 1703 to prescribe as well as dispense drugs. The only restrictions were that the apothecary was not to charge for his advice, and if the patient died on his hands, he was liable to a charge of felony—the penalty for which was hanging. (How's that for inhibiting malpractice?)

The apothecary got around that by calling in a physician if things appeared to go badly. Since he got to choose the doctor, an interesting sort of fee-splitting took place. The doctor chosen by the apothecary was likely to be one who would not express any doubts as to the treatment of the case as it stood, and in addition would prescribe yet more costly medicines for the apothecary to compound. People like Snat, the saddler, thought twice before calling in the apothecary.

A number of conscientious, public-spirited physicians had already rebelled against this system early in the century and, after several frightful fights and boycotts, had set up a dispensary at the College of Physicians, where pure, fresh drugs would be dispensed in simple mixtures at true cost. You still had to pay the doctor the guinea for his advice in order to know what to ask for, though—unless you could diagnose your own illness.

As it happens, that is just what Snat is going to do. He happens to have a copy of the First Edition (1746) of the Reverend John Wesley's *Herbal*, one of the most sensationally successful doctor books ever written. There were 32 editions in England and seven in America up to the year 1832.

Actually, if Snat had not been able to decide what was the matter, he could have gone round to Wesley's Dispensary and there received advice and medicine from a surgeon and an apothecary who were employed by Wesley, and if Snat were in real want, he could have gotten these services for nothing.

While Wesley is known today as the founder of the Methodist denomination, his fame in his own lifetime rested on his *Herbal*. With this useful book, Snat is able not only to treat the diseases, but to diagnose them as well—for the most difficult of them are described in footnotes under the proper headings.

This paper first appeared in the April 1963 issue of INHALATION THERAPY, the forerunner of RESPIRATORY CARE. Despite the passage of more than 27 years, the article's *materia medica* remains as valid today as it was then—something that cannot be said of all reprinted papers. Rosemary Young, the author, was identified in 1963 as a graduate in Design and Illustration of the Rochester Institute of Technology Art School, Rochester, New York—and as Staff Artist for INHALATION THERAPY. She now lives in Columbia, Missouri.

Snat opens his copy and sets to work. He is huddled up by a smoky sea-coal fire, reading by the light of a tallow dip. He has at hand a Turk's Head. This is an earthenware tumbler filled with gin and hot water, mixed with sugar and rather a lot of grated ginger. The vascular and tonic effects of this will soon be seen; but meanwhile Mistress Snat wonders if she hadn't better send round for the barber to bleed him a little before the "humors" thicken up on him. He really is very flushed.

(Don't laugh! people have believed in humors for centuries, and see no reason to stop. Only now, Boerhaave, the major medical pundit, has based his whole grand system on them—a system that will be in force for the rest of the 18th Century.)

But Snat is having none of the barber and his jar of gummy leeches. Here he's went and paid a shilling for Parson Wesley's book, and he's wasting no money on barbers nor apothecaries either!

Snat is not aware that in another two centuries Wesley will be regarded as a quack. Snat would regard this opinion as ludicrous, and, as a matter of fact, Snat would be right. Wesley was not a quack: He never advertised, he didn't set out to make money, he never claimed to be a doctor or a doctor's associate, nor did he insist that any of his remedies never failed. If they were generally successful as far as he knew, he said so. If he had tried them, he said that. On external evidence, it seems unlikely that he ever rejected either a really well-known folk remedy or a sensational new discovery simply because it didn't work for him. Who could tell? It might be just the thing for someone else!

Actually, John Wesley was pretty well qualified. During his long education at Oxford he had become familiar with the great medical figures of antiquity, who in the 18th Century were still the ultimate authority in many cases. He knew also the works of the best 17th and 18th Century physicians—Sydenham, Cheyne, Stahl, Boerhaave, and Haller. All this knowledge he put to practical use when he wrote his *Herbal*.

Here are two samples of Wesley's own attitudes. The first is from the postscript to the First Edition:

> VI. 1. The paffions have a greater influence on health, than moft people are aware of.
>
> 2. All violent and fudden paffions difpose to, or actually throw people into acute difeafes.
>
> 3. The flow and lafting paffions, fuch as grief and hopelefs love, bring on chronical difeafes.
>
> 4. Till the paffion, which caufed the difeafe, is calmed, medicine is applied in vain.
>
> 5. The love of God, as it is the fovereign remedy of all miferies, fo in particular it effectually prevents all the bodily diforders the paffions introduce, by keeping the paffions themfelves within due bounds. And by the unfpeakable joy and perfect calm, ferenity, and tranquility it gives the mind, it becomes the moft powerful of all the means of health and long life.
>
> LONDON, June 11, 1747.

Wesley was quite able to see the role the psyche might have in illness. How modern it sounds!

The second example is a note on the revisions of 1780. Notice the exceptional open-mindedness, and the strong ethical and religious bias. It would be hard to think of Wesley as a conscienceless quack after that!

> Otley, April 20, 1780.
>
> Since the laft Correction of this Tract, near twenty years ago, abundance of objections have been made to feveral parts of it. Thefe I have confidered with all the attention which I was mafter of: and in confequence hereof, have now omitted many Articles, and altered many others. I have likewife added a confiderable number of Medicines, feveral of which have been but lately difcovered: and feveral (although they had been long in ufe) I had never tried before. But I ftill advife, "in complicated cafes, or where life is in immediate danger, let every one apply without delay, to a Phyfician that fears God." From one who does not, be his fame

ever fo great, I fhould expect a curfe rather than a bleffing.

He was a minister first, and everything he did is colored by that. His *Herbal* is a minister's attempt to tackle the problem of human distress. It is difficult for the 20th Century to conceive the sheer misery of the sick and poor, like Snat, who were trapped between, on one hand, illnesses the cause of which was only guessed at, whose course was usually fatal, and, on the other hand, medicines that were at best noxious and ineffectual, and at worst noxious and deadly.

The *Herbal*, as we shall now see, is a curious mixture of folk remedies of very long standing—some of them being indeed the same that Nicholas Culpepper had recommended in his herbal a century before—combined with fads, superstitions, and the latest offerings of the medical faculty.

How do you suppose Snat is making out? Well, he has looked it up. The **Afthma**, that's it! Wesley says in his footnote on Page 25,

"An Afthma is a difficulty of breathing from a diforder in the lungs. In the common (or moift) Afthma, the patient fpits much."

Well, Snat's got a difficulty of breathing, all right. Fortunately, there are several things he can do about it. What! Hospitals! Hospital is a frightful word to Snat. That's the pest house, and if you go there, you're dead! Inhalation therapy? Absolutely! Right here—the Parson Wesley recommends it (along with everything else!).

It's do-it-yourself, of course. The section on asthma begins with the standard high humidity treatment:

9. The Afthma.
41. Take a pint of cold water every morning, wafhing the head therein immediately after, and ufing the cold bath once a fortnight.

Snat certainly isn't going to do that! In the first place, Mistress Snat would have to run down to the community well in the courtyard for the water, and she isn't about to go. (That's where the typhoid someone is always having is coming from, but Mistress Snat would never believe that.)

42. Or, cut an ounce of ftick Liquorice into flices. Steep this in a quart of water, four and twenty hours, and ufe it, when you are worfe than ufual, as common drink. I have known this give much eafe.

Who among us 20th Century readers hasn't ever had liquorice cough drops? Culpepper thought highly of liquorice, too, for coughs and colds. . . . care to read along with Snat?

43. Or, half a pint of Tar-Water, twice a day.
44. Or, live a fortnight on boiled Carrots only. It feldom fails.

Maybe it isn't **Afthma** at all, maybe it's . . . let's thumb through a little more. But first, what about some of these remedies?

Tar Water was discovered as a specific against the Smallpox (so much for Edward Jenner!) in Rhode Island by George Berkeley, who became an ardent supporter of the theory that Tar Water—the fluid made by shaking water and pine pitch together—would cure anything. We have such an elixir today—apple-cider vinegar and honey. There was a tremendous controversy about tar water, and much writing for and against it (sound familiar?). Wesley probably thought it could do no harm and might do some good.

Boiled carrots: According to Galen, still a powerful figure from the 1st Century, "the carrot cures colds because it makes the body soluble." Also, "a drachm's weight in carrots in white wine cures snake bites and hysteria." There it is! the origin of the classical snake-bite remedy—the only change they made was to leave out the carrots.

There's more:

45. Or, take an ounce of Quickfilver every morning, and a fpoonful of Aqua Sulphurata, or fifteen drops of Elixir of Vitriol, in a large glafs of fpring-water at five in the evening.—This has cured an inveterate Afthma.
46. Or, take from ten to fixty drops of Elixir of Vitriol, in a glafs of water, three or four times a day.

Elixir of Vitriol is made thus—Drop gradually four ounces of ftrong oil of

vitriol into a pint of fpirits of wine, or brandy: let it ftand three days, and add to it Ginger fliced, half an ounce, and Jamaica pepper, whole, one ounce. In three days more it is fit for ufe. But if the patient be subject to four belchings, take the mixture for the Afthmatic cough (as Art. 56) after the Elixir of Vitriol.

47. Or, into a point of boiling water, put a teafpoonful of Balfamic AEther, receive the fteam into the lungs, through a fumigator, twice a day.

Balfamic AEther is made thus.—Put four ounces of fpirits of wine, and one ounce of Balfam of Tolu, into a vial, with one ounce of aether. Keep it well corked. But it will not keep above a week.

We have come at last to some genuine, effective inhalation therapy—Item 47: balsamic ether steam. Here is the steam, warm and wet; here the volatile resins, mildly antiseptic. Very good; one hopes Snat tried that one. Balsam of Tolu is still used today.

The next section is **A Dry Convulfive Cough**. Snat is reasonable certain that that's not what he's got. A cough he has, but dry it isn't. All the remedies for this are straight out of Culpepper and the Saxon Leech before him.

The only modern remedy here—since 1672, that is—is ipecacuanha (ipecac) to make the patient vomit. Whatever the disease was, the standard 18th Century onslaught on it was to get the pipes cleaned out with vomits and purges.

Well, so much for the cough. Wesley also deals with cough under **Confumption**, but that is too rich and detailed a subject to deal with here. What about the headache? Snat's head feels like a super-heated battlefield, as you may imagine.

126. The Head-Ach

390. Rub the head for a quarter of an hour. Tried.

391. Or, be electrified. Tried.

392. Or, apply to each temple the thin yellow rind of a lemon, newly pared off.

393. Or, pour upon the palm of the hand a little brandy, and fome zeft* of lemon, and hold it to the forehead: or, a little ether.

394. Or, if you have catched cold, boil a handful of rofemary in a quart of water. Put this in a mug, and hold your head (covered with a napkin) over the fteam, as hot as you can bear. Repeat this till the pain ceafes. Tried.

395. Or, fnuff up the nofe camphorated fpirits of lavender.

396. Or, a little juice of horfe radifh.

*Zeft is the juice of the peel fqueezed out.

The first headache remedy is as old as headache itself, and sufferers do this almost involuntarily. The second was a real modern touch—electrotherapy had just barely been discovered in 1747, and was a terrific sensation. Wesley himself obtained a galvanic apparatus, and thousands of people were "electrified" with it. Today this would be humbug, but then it was the "wonder therapy" of the hour.

Then we have the inhalation therapies, which have long been effective. Horse radish is not too usual, but strong lemon cologne and camphorated lavender may even be familiar to many of us now. No. 394 is particularly worthy: here is the hot steam to wet the nasal passages and open the sinuses—along with an antiseptic, aromatic, highly volatile oil in the rosemary leaves.

What about the unfortunate saddler's sore throat? He needs only to look under **The Quinsy** in order to fix it up. **The Quinsy** could have been any of several diseases from tonsillar abscesses to strep throat:

183. The Quinsy

565. Apply a large white-bread toaft, half an inch thick, dipt in brandy, to the crown of the head, til it dries:

566. Or, fwallow flowly white rofe-water, mixed with fyrup of mulberries. Tried.

567. Or, juice or jelly of black currants, or decoction of the leaves or bark.

568. Or, draw in, as hot as you can bear, (for ten or twelve minutes together) the fumes of red rofe-leaves, or camomile-flowers, boiled in water and vinegar: or, of a decoction of bruifed hemp-feed.

This fpeedily cures the fore-throat, peripneumony, and inflammation of the

uvula. See Extract from Dr Tiffet, page 41.

Wesley's remedies here are designed to give symptomatic relief, and they do this well—especially the steam treatment. The rose leaves are a magic hangover from Culpepper and before, but the camomile is in the class of antiseptic aromatics. The hemp seed is exactly what you think it is: Indian hemp or marijuana or Pot, or however you call it. It might not cure a sore throat, but it would take your mind off it.

The large white-bread toast is curiously misplaced. What it should be is a hot bread-and-milk poultice applied to the outside of the throat—this with gargles of sal ammoniac and spirits of vitriol—according to the *London Practice of Physics*, published at about the same time as Wesley's *Herbal*. Along with these severe gargles, the vapor of emollient plants is directed to be drawn into the throat through a funnel.

At this long distance we will have to hope that all Snat had was a peach of a cold. Anything more serious, like pneumonia, and Snat would have been pretty much out of luck. Even with the prompt attention of the very best physicians, he'd have fared no better than he did with Wesley—maybe not as well.

To the victim of respiratory diseases it was not much comfort to know that these diseases, while often confused with one another, were pretty well described by 1750, and in another 11 years the appearance of the morbid lung in terminal pneumonias would be known from postmortem dissections. In spite of this, and in spite of pretty good anatomical knowledge of even some of the finer structures, the true function of the lungs was not known. What actually happened to the air that went in and out, and why people suffocated without it, was a profound mystery that would have to wait for almost another century for the work of three mathematicians, two physicists, and five chemists.

Meanwhile, Boerhaave didn't know, nor the Hunters, nor Van Swieten nor Halles—nor, indeed, the Reverend Wesley— no one really knew.

But there was something about the air, and here is the empirical proof that people were aware of this elusive something. Direct your attention to **No. 466**, all you up-to-date mouth-to-mouth resuscitators!

149. For one feemingly killed with Lightning, a Damp, or fuffocated

465. Plunge him immediately into cold water.

466. Or, blow ftrongly with bellows down his throat. This may recover a perfon feemingly drowned. It is ftill better, if a ftrong man blows into his mouth.

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Pulmonary Physiology: Fetus, Newborn, Child and Adolescent, 7th ed, edited by Emile M Scarpelli MD PhD. Philadelphia: Lea and Febiger, 1990. $89.50.

The field of pediatric pulmonology has undergone major changes since the first edition of this book was published in 1975. This new edition has been extensively rewritten with increased emphasis on topics such as cell matrix interactions and molecular biologic determinants of growth and development.

This multi-authored book draws from the strength of its contributors. All the chapters have been either extensively rewritten or are new to this edition. There are excellent chapters on pulmonary solute and liquid balance, pulmonary mechanics and ventilation, and normal pulmonary circulation. The exciting new technique of magnetic resonance spectroscopy and its potential usefulness in evaluating cellular respirations is covered in a chapter authored by Drs Maria Delivoria-Papadopoulos and Britten Chance.

Although this is a multi-authored text, there is very little duplication of information, the text is readable and the diagrams and drawings are clear. Overall, this is an excellent overview of pulmonary physiology in children, and should be in the library of anyone who cares for infants with respiratory disease.

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The Ventilator Assisted Patient: Preparing For Home, by Philip M Gold MD, Tony Hilton RN MPH CRRN, David McLean RRT MPH RCP, Julie Sconza RN BSN, and 22 contributors. Hardcover, 400-pages, illustrated; 3-ring binder with optional 25-minute 1/2" VHS videotape. California: Loma Linda University Medical Center, 1989. $350.00 for manual/video package. Manual alone $225.00, video alone $75.00. Phone orders accepted with credit card (714) 824-4495.

This manual was designed to aid hospitals in the formulation of a hospital-based discharge-planning and continuing-care program for the ventilator-assisted patient. The manual's 10 sections provide sample hospital policies and procedures; staff, patient, and caregiver training guidelines; and letters that can be modified and sent to insurance companies and community service agencies. The 3-ring binder allows users to remove segments of the manual for copying and modification for use in their own home-ventilator discharge-planning program. The reader should note the copyright that states that those portions of the manual developed by Loma Linda University Medical Center (LLUMC) must not be reproduced in their entirety without Loma Linda's prior permission. Even so, the procedures and forms are excellent guides.

The first chapter, Program Organization, is a comprehensive overview of the entire program, which the authors refer to as the Ventilator Assisted Patient Education Program (VAPEP). This first chapter (in outline form) presents a clear picture of the patient's progress through the program—from collection of pre-admission data to discharge and continuing care at home. The no-nonsense tone of the VAPEP is established in this chapter. The lay primary caregiver is expected to eventually become the coordinator of all patient-care activities, including communication with all agencies and health-care team members involved with the patient's care, discharge training, and post-acute continuing care. LLUMC team members assess (1) the willingness of the patient and the caregiver(s) to have the patient return home and to actively participate in training, discharge planning, and ongoing coordination of after-discharge care; (2) the adequacy of financial resources to support the home care process; (3) caregiver participation in all conferences and training sessions as scheduled; and (4) the ability of caregivers and patient to communicate in English. Such assessment, participation, and attention to detail by the program staff, primary caregivers, and patient are vital to a truly successful hospital-to-home experience. Chapter 1 supplies a sample caregiver contract that details the caregiver's responsibilities and the learning objectives of the program and a sample objective-based training record that requires caregiver and instructor to sign-off each trained skill as it is completed. The contract and record not only offer an organized format for training throughout the program, but also serve as evidence of caregiver competence as stated by the caregiver, thereby reducing the program's potential liabilities.

Chapter 2, Policies and Procedures, provides hospital policies and procedures that detail staff responsibilities in the discharge and training processes utilized within the VAPEP. A number of policies and procedures in this section ask the reader to refer to another administrative policy for further clarification or detail within the present policy. In error at times, the referenced policy identification has been left blank and thus the reader is at a loss. Example: Page 2-A operating policy entitled "Admission of Ventilator-Assisted Patients for the Purpose of Rehabilitation," Section 2,

Point 2.3, states "The Patient Meets All Admission Criteria for Entry into the VAPEP." (ref: Administrative Policy M-) and also Page 2-B procedure entitled "Admission of Ventilator-Assisted Patients for the Purpose of Rehabilitation," Section 4, Point 4.6, states "Commitment from the caregiver to participate in the VAPEP and to subsequently provide the necessary patient care at home post discharge" (reference administrative policy M-). A number of omissions of information exist in statements made within the clinical portions of some of the procedures and policies. Example: Page 2-F Patient Care Protocol entitled "Standard Care of Patient Being Weaned from a Ventilator," Section 2, Point B, states "A forced Vital Capacity 10mg/kg, and Section 2, Point H, states "VD/VT 60%."

An additional point in question in Chapter 2 is a pharmacy policy entitled "Home Parenteral Nutrition." Point 3 states "A charge of $1,000.00 shall be made for the home parenteral nutrition training course." I question this practice considering that outside agencies will provide enteral/parenteral services to the client without charge for a 'program.'

I believe the policy entitled "Guidelines for Handling the Death of the Ventilator Dependent Patient in the Home" to be a weak, scanty policy that could lead to confusion and possible legal ramifications. The policy states in Point 3 "If the patient expires, the family is permitted to disconnect the patient from the ventilator." This policy does not outline the responsibilities of the physician in this scenario and leads the reader to assume that the family can determine death without the presence or consultation of a physician. Conversely, Chapter 10 Ethical/Legal Considerations, a detailed dissertation on the physician's role in determining death, could serve to clarify the earlier policy.

Although Chapter 2 is a weak segment of this large manual, it does contain some valuable and relevant information.

Preadmission Screening (Chapter 3) contains a detailed patient evaluation form, sample letters of acceptance and denial of a patient to the referral institution, and a complete caregiver program form—valuable forms that can be customized for use in any program.

Chapter 4, Team Member Roles, solidifies the concept of the multidisciplinary health-care team—the core of any successful home-ventilator discharge program. The responsibilities of each team member including the lay caregiver are identified in detail.

Staff Education (Chapter 5) provides outlines of standard care routines such as suctioning, tracheostomy care, and bronchial drainage. Protocols written for specific home-care procedures are general and will require much customization. The general, nonspecific nature of the material in this chapter is probably necessary because of the wide variety of equipment and techniques popular from region to region. A 6-page very simplistic Glossary of Terms contains such terms as air sacs, airway, alveoli, bagging, COPD, and diaphragm. Chapter 5 concludes with a 6-page bibliography. The bibliography includes many experts in their relative fields, but could be updated to more current times.

Chapter 6, Patient/Caregiver Education, is a valuable compilation of instructional aids for any home-ventilator training program, listing training aids ranging from manufacturers' literature and manuals to specifically written procedures for techniques (such as disinfecting and reusing suction catheters) and instructions for administering subcutaneous injections and preparing balanced meals.

Chapter 6 also includes a complete listing of training objectives to be completed by the patient and caregiver before 'graduation' from the VAPEP. The certificate of completion found in the chapter is to be awarded to patient and/or caregiver after successful completion of the program. This chapter can be an invaluable aid to any program, whether hospital- or community-based.

Documentation and Forms (Chapter 7) is a collection of forms used throughout the home-going process—an agency resource list with names and phone numbers, a discharge-orders form, a medication schedule for use in the home, and a program coordinator checklist to ensure that all facets of the program have been completed prior to final discharge. A sample letter to be sent to apprise utility companies of the presence of a life support system in their service area is included. All forms in this chapter are pertinent and necessary to any program.

Chapter 8, Third Party Payors, is a unique chapter in that it offers sample letters of medical necessity, requests for specialized equipment and processes such as total parenteral nutrition, detailed plans of care and treatment, and a cost analysis comparing hospital to home-care costs—information necessary for insurance carriers to make informed policy decisions regarding care of the ventilator-dependent patient, which may be unusual for them. This chapter can be of great assistance in obtaining timely reimbursement for this complex type of home care.

Chapter 9, Cost Comparisons, in two short pages compares not only costs but also problems, interventions, and evaluations for ventilator-assisted patients in hospitals as they compare to skilled nursing facilities and private care at home—a valuable aid in determining benefits from an insurance carrier.

Chapter 10, Ethical/Legal Considerations, provides an interesting addendum by presenting guidelines concerning life sustaining treatment as

developed by the Los Angeles Medical Association and Bar Association. Although these guidelines may not pertain from state to state, they do offer food for thought and considerations to be investigated in one's own community.

I viewed the 25-minute videotape after I had reviewed the manual. The tape summarizes the pertinent points and issues within the VAPEP manual. The videotape is professionally produced and offers a clear and concise overview of the entire training program, with a number of interesting patient and caregiver interviews. The tape may not be of substantial value for the hospital staff member who reviews the manual, but should be of assistance in summarizing the program for the patient and caregiver. The patient interviews may answer many questions and may also provide reassurance to some patients and their families who may be hesitating to take that first 'step' toward home.

It is obvious that the LLUMC editors and contributors have accumulated a substantial history and knowledge base associated with the discharge planning and training of ventilator-assisted patients and their families. The VAPEP offers a wealth of useful information that can be applied to both institution- and community-based home-ventilator programs.

This program effectively addresses issues of organization, caregiver-patient responsibilities, and reduction of health-team-member liability in this involved and complex aspect of home care.

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Measuring End-Tidal Carbon Dioxide Tension at Maximal Exhalation To Improve Its Utility during T-Piece Weaning Trials

The measurement of end-tidal carbon dioxide tension (P_{etCO_2}) can be helpful in the management of mechanically ventilated patients who are considered candidates for T-piece weaning, provided P_{etCO_2} coordinates reasonably well with arterial carbon dioxide tension (P_{aCO_2}). Hoffman et al found that the substitution of P_{etCO_2} for trends of P_{aCO_2} may be misleading in intubated critically ill patients due to an inconsistent P_{etCO_2}-P_{aCO_2} gradient.[1] One problem in this regard is the patient whose breathing pattern and, therefore, his P_{etCO_2}, are quite variable. We report a case of this sort and describe how we overcame the problem of P_{etCO_2} variability.

The patient was a 44-year-old man with renal-cell carcinoma who underwent a right nephrectomy and tumor thrombectomy. There was no history of respiratory impairment. He was weaned from mechanical ventilation on Postoperative Day 2. On Postoperative Day 3, he exhibited neurological changes characterized by disconjugate gaze and decreased gag reflex. On Postoperative Day 8, he developed respiratory failure requiring endotracheal intubation and mechanical ventilation.

Mechanical ventilation continued for the following 50 days because several attempts at weaning were interrupted by periods of apnea, apparently as part of an ongoing neurological process. On Postoperative Day 59, a T-piece-method weaning schedule[2] was initiated, with continuous monitoring by a Novametrix 1250 capnometer (Novametrix Medical Systems, Wallingford CT) and a Physio-Control 1600 pulse oximeter (Physio-Control Inc, Redmond WA). The patient's spontaneous respiratory pattern remained irregular in rate and tidal volume. The initial P_{etCO_2} recordings varied from 20 to 58 torr (Fig. 1, upper panel) and could not be accepted as good estimates of P_{aCO_2}.

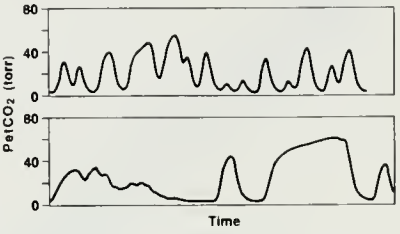

Fig. 1. Capnograms during spontaneous breathing through a T-piece by a 44-year-old man with abnormal respiratory drive. The upper tracing shows an irregular respiratory pattern and variability of P_{etCO_2}. In the lower tracing, the third waveform from the left is an exhalation achieved by an FVC maneuver. The P_{etCO_2} recorded at the end of this exhalation correlated well with the P_{aCO_2} analysis from simultaneously drawn arterial blood. Upper and lower tracings were recorded on the same day.

Tulou and Walsh had reported close approximation of P_{aCO_2} and P_{etCO_2} in nonintubated patients with COPD if the P_{etCO_2} was measured at the end of maximal exhalation.[3] Encouraged by that report, we asked our patient to perform a forced vital capacity (FVC) maneuver (maximal inspiration followed by maximal exhalation) while breathing spontaneously via the T-piece. The P_{etCO_2} measured at the end of maximal exhalation was 60 torr. Analysis of simultaneously drawn arterial blood revealed values of pH 7.35, P_{aCO_2} 63 torr, and P_{aO_2} 95 torr.

During the T-piece trials, the P_{etCO_2} at the end of maximal exhalation was measured a minimum of every 2 hours. To ensure reproducible results, a minimum of two FVC maneuvers was performed by the patient for each P_{etCO_2} recording. During spontaneous breathing, the P_{etCO_2} was always variable, whereas at the end of a maximal exhalation it was consistently stable. The capnograms provided documentation of an irregular respiratory pattern and confirmed that the patient had indeed performed an FVC maneuver (Fig. 1, lower panel).

The duration of spontaneous ventilation through the T-piece was gradually increased as long as the P_{etCO_2} after maximal exhalation was < 70 torr, or oxygen saturation measured by pulse oximetry (SpO2) was $> 93\%$, or a predetermined time period was reached. Arterial blood gases were analyzed approximately every 3 to 6 days to determine how they correlated with S_{pO_2} and P_{etCO_2} at the end of maximal exhalation. The P_{aCO_2}-P_{etCO_2} gradient was from 3 to 12 torr, as illustrated in Table 1. Ideally, simultaneous P_{etCO_2} and P_{aCO_2} should be compared each day.

The patient was eventually weaned from mechanical ventilation during the day and evening. However, because of his neuromuscular dysfunction, ventilatory support was required for approximately 5 hours each night.

Table 1. Comparison of P_{aCO_2} and P_{etCO_2} Values of 44-Year-Old Man in Respiratory Failure during T-Piece Weaning from Mechanical Ventilation

Day	P_{aCO_2} (torr)	P_{etCO_2} (torr)	Gradient (torr)
59	48	42	6
65	82	70	12
78	67	64	3

As Tulou and Walsh had reported,[3] we found that P_{aCO_2} and P_{etCO_2} correlated closely in our patient only when P_{etCO_2} was measured at the end of maximal exhalation. The consistently stable P_{etCO_2} readings secured in this way enabled us to use the capnometer in conjunction with the continuous pulse oximeter as a guide to the safe limits of T-piece breathing duration.

To summarize, the use of capnometers is limited in patients with variable P_{etCO_2} levels. We eliminated the variability in one patient by recording the P_{etCO_2} exclusively at the end of a maximal exhalation. This technique may provide an alternative noninvasive assessment of ventilation—and it may facilitate weaning from mechanical ventilation—in selected patients.

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Preventing Obstruction of an HMEF

Randy De Kler has suggested in a letter published in this journal[1] that a potential hazard associated with use of the Conserve heat and moisture exchanging filter (HMEF) is partial or total obstruction of the filter by bronchial secretions.

I have devised a trap (Fig. 1) consisting of a Bird T-Piece (internal diameters, 22 mm, 22 mm, and 15 mm) connected by the 15-mm orifice to a Portex Connector (patient swivel connector). The opposite 22-mm orifice is connected to a Bird Adapter (outside diameter, 22 mm) and a 6″ corrugated flex tube with the distal end capped. The tube serves as a receptacle for the patient's secretions. The upper 22-mm orifice is attached to an elbow (outside diameters, 22 mm and 15 mm) and to the HMEF. Pointing the HMEF upward guarantees that it will remain free of secretions.

Fig. 1. A secretion trap designed to prevent the obstruction of a heat and moisture exchanging filter with secretions.

Although the connectors and the trap itself may add to the dead-space volume of the ventilator circuit, the effect appears to be negligible in the breathing circuit of an adult patient. We use this trap only for adult patients ventilated with a tidal volume of 500 mL or more. We checked the effect of the added volume for 6 days on all of the ventilated adult patients in our RICU (4-5 patients/day) and found no increases in P_{aCO_2} attributable to the device. The net weight of the trap is about 50 g.

The trap has been used in the Hebrew University Medical Center of Hadassah Hospital, Ein Kerem, Jerusalem, Israel, since November 1988.

Yekutiel Steltzer
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Jerusalem, Israel

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Hypnosis Societies

Since the publication of my letter to the editor of RESPIRATORY CARE,[1] I have received requests for information on hypnosis organizations, training, and certification programs. From personal experience the following three professional societies have served me well in understanding this important therapeutic adjunct.

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Each year a highlight of the Annual Meeting of the American Association for Respiratory Care, the RESPIRATORY CARE Open Forum, provides a platform for the reporting and discussion of some of the clinical studies, method and device evaluations, and case reports completed by members and friends during the previous year. During the 1990 Open Forum in New Orleans, Louisiana, December 8-11, more than 90 papers will be presented—clustered into groups of similar topics or into minisymposia. The abstracts of those papers are published here, sequenced as they will be presented. An index of the authors appears on Page 1147, with Presenters designated by boldface type.

Quality Assurance and Infection Control Measures

Influence of Mode of Ventilation on Accuracy of Therapist-Reported Pulmonary Artery Occlusion Pressure Measurements—Patricia A Doorley RRT, Charles G Durbin Jr MD. University of Virginia Health Sciences Center, *Charlottesville, Virginia.*

Pulmonary artery occlusion pressure (PAOP) measurements are used for diagnosis and to guide fluid management in patients in shock or with ARDS. Measurement accuracy may be affected by catheter-tip position within the lung, resonance in the vascular tree or in the transducing system, calibration (and zeroing of the monitor), and relationship to the respiratory cycle. Readings must be obtained at end-exhalation to minimize effects of respirator-induced artifact. The ventilation mode determines where on the PAOP tracing the end-exhalation reading should be made. We hypothesized that during mixed modes of ventilation (spontaneous and positive pressure) accuracy would be less than during solely spontaneous or solely positive pressure ventilation. **Methods**: As part of our quality assurance program, we randomly selected 61 strip-chart recordings of PAOP to assess the accuracy of measurements reported by respiratory care practitioners (RCPs). According to departmental policy, RCPs routinely document mode of ventilation, ventilator settings, and measurement point for each PAOP measurement that is recorded. We independently evaluated the PAOP tracings, and determined 'correct' values. In each ventilation group (S = spontaneous ventilation ± CPAP; P = positive pressure ventilation ± PEEP [PSV, PC, and AC]; MXD = spontaneous and positive pressure ventilation ± PEEP [IMV and SIMV ± PSV]), correct values were compared to those reported in the medical records by RCPs, and the significance of differences was determined by ANOVA and paired Student's *t* test. **Results**: 60 of the 61 randomly selected records were considered adequate for the purpose of our study.

Comparison of Correct and RCP-Reported Values for PAOP*

Group	n	RCP-Reported PAOP	Correct PAOP	Error	p
S	19	17.2 (10.3)	17.8 (10.0)	1.3	0.163
P	19	16.9 (6.4)	16.8 (5.5)	1.1	0.897
MXD	22	15.5 (5.1)	16.0 (5.4)	1.45	0.348
All	60	16.5 (7.4)	16.8 (7.1)	1.31	0.663

*PAOP is reported as mean (SD) in torr.

No significant differences were seen between correct and RCP-recorded values or error in any group or data as a whole ($p = 0.750$). In five patients, inappropriate recording sensitivity was used but did not affect accuracy. In four patients, a regurgitant V-wave was correctly recognized by RCPs, and appropriate PAOP was determined. Only three measurements had an error > 3 torr; the largest error was 8 torr. **Conclusions**: Our findings suggest that mode of ventilation does not affect accuracy of RCP-reported PAOP measurements. However, monitoring the accuracy of reported PAOP is a useful quality-assurance tool to use in cardiovascular services. (OF-90-005)

Reduction of Chest Physiotherapy by a RCP-Initiated Discontinuance Policy—William R Anton RRT. University of Washington Medical Center, *Seattle, Washington.*

An audit conducted at my hospital, as part of ttory Care Department quality-assurance program, revealed that in 1988 a high percentage (64%) of physician orders for chest physiotherapy (CPT) were inappropriate. Therfore, a policy was developed for discontinuance of CPT. **Method**: Upon receipt of an order, the patient is evaluated and/or CPT is initiated to determine efficacy. CPT is considered inappropriate and discontinued if (1) the patient is ambulatory and does not have an inherent need for therapy (eg, cystic fibrosis or bronchiectasis)

or (2) sputum has not been produced (during or within 30 min of therapy) after three consecutive treatments. When criteria #1 is met, the physician is notified by phone. When criteria # 2 is met, the physician is notified via a sticker placed in the chart that reads: "Doctor, CPT discontinued. No evidence of sputum production after three treatments. Please obtain a Pulmonary Consult if you wish assistance with diagnostic workup or alternative therapeutic measures." **Results**: A subsequent audit revealed that in 1989 only 20% of physician orders for CPT were inappropriate by the predetermined criteria. The number of CPT procedures performed decreased from 7,946 in 1988 to 6,562 in 1989 (a decrease of 1,384 procedures). **Discussion**: CPT decreased in spite of the advent of an adult cystic fibrosis clinic in 1989. CPT of both lungs is allotted 38 minutes of RCP time. By Respiratory Care Department productivity criteria, the decrease of 1,384 CPT procedures in 1989 translates to 0.76 FTE. Inappropriate orders for CPT have decreased from 64% to 20%. Feedback received from the RCP staff indicates that staff morale has improved because of the increased RCP control over unnecessary CPT. **Conclusion**: RCP-initiated discontinuance of CPT can decrease total CPT procedures, increase the percentage of appropriate CPT, and improve RCP morale. (OF-90-032)

Monitoring the Quality of a Hospital-Based Oxygen Utilization Program—Steve Kessinger BA CRTT, Saint Mary's Regional Medical Center; John Steinmetz BS RRT, Hamilton Medical Inc—*Reno, Nevada.*

In response to the need for reduced costs and a perception that oxygen therapy was over utilized, we developed an oxygen therapy utilization program at our facility. **Program Description**: Accepted guidelines were established based upon literature review and physician input. Patients are monitored by 'spot check' pulse oximetry (Model 505, Novametrix, Wallingford CT) 24 hours after initiation of oxygen therapy, and at 72-hour intervals thereafter. A target range of 88-92% S_{pO_2} is desired. Patients with $S_{pO_2} < 88\%$ are immediately assessed for clinical evidence of desaturation. Potential mechanical causes of desaturation readings are also investigated and corrected (if applicable). The patient's physician is then contacted and measures are taken to manage the situation, based upon his/her orders. Charts of patients with $S_{pO_2} \geq 92\%$ are reviewed for exclusionary criteria: CVA that has occurred within 72 hours, reduced hemoglobin (< 10 g/dL), current cardiac dysrhythmias, history of unstable oxygen saturation, and other conditions deemed relevant by the respiratory care practitioner (RCP). Charts of patients with no apparent exclusionary criteria are tagged for physician review and RCP recommendations to reduce or discontinue oxygen therapy are clearly written. Physicians are then given 24 hours to respond to these recommendations. For quality assurance purposes, we monitor the number of oximetries done each month, number of recommendations to change current therapy, number of recommendations that elicit a physician response, and number of recommendations that fail to elicit a physician response. When recommendations fail to elicit a physician response, the situation is reported to Medical Staff Services for follow-up by each subspecialty chairperson. Noncompliant physicians are listed by a four-digit code and patients by their admission number. **Results**: Within a 3-year period of using this program, the mean number of hours of oxygen use per patient (for whom oxygen was prescribed) decreased from 91 to 75. During 1989, the percentage of physicians not responding to RCP recommendations concerning oxygen therapy decreased from 10% to 2%. **Conclusion**: Our experience suggests that this type of oxygen therapy utilization program can be implemented by RCPs, is readily accepted by physicians, and is a means to ensure appropriate use of oxygen therapy. (OF-90-035)

Scavenging Ribavirin from an Oxygen Hood To Reduce Environmental Exposure—Deborah P Stevens BA RRT, University Hospital-Hershey Medical Center, *Hershey, Pennsylvania.*

I describe a scavenger system developed at my institution for reducing environmental exposure to ribavirin aerosol. Ribavirin aerosol that would be otherwise free-floating is recaptured through use of an oxygen hood system. The oxygen hood is modified by making 22-mm-ID holes into which 22-mm-OD, adapters are placed. Wide bore tubing is attached and connected to a Y-connector, a bacterial-viral filter, and wall suction. Flows from the SPAG-2 into the oxygen hood and from the suction through the filter are measured with a Wright respirometer and suction flows are adjusted to about 1 L/min greater than SPAG-2 flows. During operation, flows are measured and adjusted q 2 h. The National Institute of Occupational Safety and Health (NIOSH) assisted in evaluating the scavenger's effect upon ribavirin concentration inside the oxygen hood and the scavenger's ability to decrease the amount of ribavirin released into the surrounding atmosphere. **Method & Materials**: Air samples were collected on 37-mm glass-fiber filters in closed-face cassettes connected to sampling pumps over an 8-hour period on two consecutive days while a SPAG-2 delivered ribavirin into a modified oxygen hood. An infant CPR mannequin (Resusci Baby, Laerdal Medical Corp, Armonk NY) was placed into the oxygen hood to simulate placement of an infant. F_{IO_2} inside the oxygen hood was analyzed and remained stable at 0.88-0.89 throughout both sampling days. Filters were placed at 5 locations: (1) on the cheek of the mannequin inside the oxygen hood, (2) at the head of the crib 3 ft from the oxygen hood; (3) on the countertop 4 ft from the crib, (4) on the window ledge 8 ft from the oxygen hood, and (5) on the wall ledge 11 ft from the oxygen hood. NIOSH analyzed the filters and determined time weighted averages (TWA) for Day 1 with the scavenger in use and for Day 2 without the scavenger. **Results**: The filters inside the oxygen hood were overloaded with Ribavirin, making it impossible to report actual concentration at Location 1. TWA (in $\mu g/m^3$) for Day 1 vs Day 2 in the four locations outside the oxygen hood were: (2) 1230.4 vs 859.1, (3) 32.5 vs 1027.1, (4) 43.7 vs 428.5, and (5) 95.5 vs 554.2. **Discussion**: The collection procedure for high concentration areas has been modified, and I will be resampling inside the hood. The higher TWA at the head of

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the crib (Location 2) is attributable to flow measurements, made q 2 h at this location, that required the tubing to be disconnected and allowed ribavirin to escape into the immediate environment. **Conclusion**: The scavenger appears to be an effective means to contain ribavirin (an otherwise free-floating drug) and to protect health care professionals from the potential danger of repeated environmental exposure. (OF-90-040)

Universal Precautions Monitoring in Respiratory Care—Virginia C DeFilippo MS RRT, Richard W Bowen BS RRT, Yale-New Haven Hospital, *New Haven, Connecticut.*

The Occupational Safety and Health Administration (OSHA) has proposed compliance monitoring of universal precautions (UP) as recommended by the Centers for Disease Control (CDC). Our Respiratory Care (RC) department has developed and implemented a data collection tool for UP monitoring. **Method**: Task-specific department standards were established by numbering RC tasks (eg, ventilator monitoring, CPR, oxygen administration) and task-specific minimum barrier precautions to be employed (ie, hand washing, gloves, gowns, goggles, masks). Supervisors, during their daily activities and without the therapist's knowledge, directly observe tasks being performed, and then enter onto a data collection sheet the therapist's name, task number, barriers employed, and remedial action (if noncompliance is observed). Supervisors are required to submit 16 observations per month. Quarterly data are reviewed, observations are entered into individual employee UP monitoring records, and a task is selected for a retrospective department study on UP compliance. The initial task monitored was suctioning (53 suctioning procedures were monitored). Our hospital's Epidemiology and Infection Control department also independently monitored the RC staff's UP compliance during suctioning. **Results**: A 100% compliance rate was found by both the RC department and the hospital's Epidemiology and Infection Control department, demonstrating the reliability of the results. **Discussion**: The ongoing monitoring serves several functions. Documentation of employee compliance satisfies OSHA's requirement and is used in annual employee performance reviews. The quarterly summary report is a tool utilized by the RC department's Quality Assurance committee and the hospital's Epidemiology and Infection Control department to identify problems and to address further educational needs. **Conclusions**: This standardized reporting tool has been easy to use in the course of normal supervisory activities and appears to yield reliable results. (OF-90-112)

Contamination of Heated Neonatal Ventilator Circuits—Patricia A English MS RRT, Robert M Kacmarek PhD RRT, Nancy Vallande BS MT, Cyrus C Hopkins MD, Massachusetts General Hospital, *Boston, Massachusetts.*

As a result of the development of condensate in neonatal ventilator tubing, aspiration of condensate, and the mandate to exercise universal precautions, we now use heated isothermal custom pediatric ventilator circuits (Baxter Pharmaseal, Valencia CA) and Concha Thermal-Plus humidifiers (RCI, Arlington Heights IL) on all neonatal ventilators. Because water does not condense in these tubes, we questioned whether system contamination was still a major problem and whether circuit use could be extended beyond a 48-hour limit. **Methods**: All heated neonatal ventilator circuits were used until the 1.5-L feed of the Concha was empty; then, the circuit, water-feed system, and humidifier canister were removed, bagged, and sent to our infection control laboratory. Swab cultures of the Y-connector and humidifier canister were performed, and a broth washing of the 18 inches of inspiratory circuit closest to the patient was performed. **Results**: 107 circuits (in place from 24 to 128 hours, used on 43 different patients) were cultured. None of the humidifiers were positive; however, 11 of the inspiratory circuits and 43 of the Y-connectors were positive (ie, a total of 43 of the 107 circuits were positive). When possible, swab culture and broth-washing culture results were matched to results of sputum cultures; however, sputum culture results were not available on all patients. Of the 43 positive Y-connector cultures and 11 positive inspiratory-circuit cultures, only 5 cultures showed organisms not identified in sputum specimens, although, in 3 of these no sputum culture results were available. **Conclusion**: These preliminary results tend to support the acceptability of extending heated neonatal-ventilator circuit use beyond 48 hours. However, additional data are required before recommendations can be made. (OF-90-143)

Bacterial Migration through Infant Ventilator Circuits—Timothy A Williams RRT, Miami Valley Hospital; Laura Elder PhD, Miami Valley Hospital/Compunet Clinical Laboratories—*Dayton, Ohio.*

The purpose of this study was to evaluate the migration of bacteria through infant ventilator circuits from contaminated humidification systems. **Methods & Materials**: Four Infant Star ventilators (Infrasonics Inc, San Diego CA) were set up with disposable circuit components as follows: 0.2 µ Bourns bacteria filter (Bear Medical Inc, Riverside CA), MR-320 humidifier chamber (Fisher & Paykel Inc, Auckland, New Zealand), and dual-heated-wire infant disposable ventilator circuit (Marquest Medical Inc, Engelwood CO). One ventilator was used as a control, the other three were contaminated with a heavy growth ($> 1 \times 10^8$ organisms/mL) of *Pseudomonas aeruginosa, Staph aureus*, and *Pseudomonas cepacia*. Cultures were sampled from the humidifier chamber, humidifier outflow, and the patient connection at 0, 3, 5, 7, and 10 days. The ventilators were cycling in the continuous-flow mode at flowrate 10 L/min, breathing frequency 20/min, airway pressures 24/4 cm H_2O, and inspiratory time 0.5 s. The patient connector was capped to allow airway pressures to be generated. **Results**: Throughout the 10-day period all cultures obtained at the patient airway connection were negative and cultures obtained at the humidifier outflow were negative with the exception of one due to a sampling error. All of the humidifier chambers grew out their respective organisms, but by Day 5 all chambers were found to be sterile, indicating that the heat generated is adequate to pasteurize the humidifier water. **Conclusions**: This pilot study suggests that pass-over/wick-type humidification

does not transmit bacteria from a contaminated humidifier chamber to the patient connection of the ventilator circuit. Therefore, we question whether the commonly accepted practice of changing ventilator circuits as frequently as every other day, which is costly and potentially compromising to the patient, is justified. To further investigate the findings of our study and to increase the 'power' of the results, we are conducting another study of similar design with a larger number of ventilators. (OF-90-006)

Selected Topics

An Analysis of Job Satisfaction among Respiratory Care Practitioners—David C Shelledy PhD RRT, John W Youtsey PhD RRT. Georgia State University, *Atlanta, Georgia.*

The purpose of this study was to determine among respiratory care practitioners (RCPs): (1) What organizational or job-specific variables are associated with increased job satisfaction? and (2) What personal, professional, or demographic characteristics are associated with increased job satisfaction? **Method**: A three-part assessment instrument was assembled—Part I consisted of the Job Analysis Survey for RCPs (a 76-item survey that assesses organizational factors; job-specific variables; demographic, professional, and social support variables; and two outcome variables—attrition and absenteeism), which was reviewed by a panel of experts to establish content validity and pilot-tested to establish test-retest reliability; Part II consisted of the Job Descriptive Index; and Part III consisted of the Staff Burnout Scale for Health Professionals. The instrument was distributed to all active credentialed RCPs in a large southeastern state (n = 788). Ten percent of non-respondents were randomly sampled and interviewed by telephone (n = 33), and the results were compared to those of the respondents. Variables were compared to job satisfaction scores using the Pearson Product-Moment correlation. Multiple regression analysis was performed to determine the ability of the significant variables to predict job satisfaction when used in combination. **Results**: There were 465 usable returns for a response rate of 59%. There was no significant difference in job satisfaction between study respondents and nonrespondents ($p = 0.24$). There were 39 significant ($p < 0.05$) predictors of overall job satisfaction, which accounted for 69% of the variance observed ($r = 0.83$; $p < 0.0001$). Based on regression analysis, the strongest organizational and job-specific predictors of increased job satisfaction were a positive organizational climate, increased job control, job independence, supervisor and co-worker support, and respect of nursing. The strongest personal, professional, and demographic predictors of improved job satisfaction were age, decreased absenteeism, and lower levels of professional burnout. **Conclusion**: Maximizing factors that contribute to job satisfaction should improve patient care, productivity, absenteeism, and attrition. (OF-90-025)

Long-Term Effects of Organic Dust Toxicity Syndrome—Dominic P Coppolo RRT, John J May MD, The Mary Imogene Bassett Hospital, *Cooperstown, New York*; Laura Marvel RN, David S Pratt MD, The New York Center for Agricultural Medicine and Health, *New York, New York.*

The organic dust toxicity syndrome (ODTS) is a febrile illness occurring several hours after exposure to an environment heavily contaminated with organic dust. Little is known about the long term effects of this disorder, but our clinical experience suggested that heightened airway reactivity might be one of the sequelae. This study was designed to investigate the long-term respiratory effects of ODTS. **Method**: Twelve farm workers included in a series of acute ODTS cases previously described were studied approximately 5 years after their documented episodes. These individuals were representative of the group as a whole and were selected because of their willingness to participate and proximity to our facility. Symptoms were assessed with the modified British Medical Research Council questionnaire. Pulmonary function testing (PFT) including basic spirometry (FVC, FEV_1), lung volume (RV, TLC), and carbon monoxide diffusion (KCO) was performed on all participants. Results are described as percent of predicted normals for age and height. All subjects underwent bronchial challenge testing using methacholine as described by the American Thoracic Society. Results of positive challenges are described as the cumulative dose of methacholine required to produce a 20% reduction in FEV_1 ($P_{D_{20}}$). Each of these individuals have been matched by age, smoking history, and sex with farmers who have had routine occupational dust exposures but have not experienced symptoms of ODTS, and with similarly matched controls who had never worked in a farming environment nor experienced symptoms of ODTS. **Results**: Pulmonary function results are reported as percent of predicted (± SD):

	Exposed Farmers	Control Farmers	Normal Controls
FVC	90.0 (13.3)	93.2 (15.0)	96.3 (11.7)
FEV_1	91.7 (13.8)	97.2 (16.0)	96.0 (11.8)
RV	93.6 (23.2)	106.8 (31.3)	96.5 (13.1)
TLC	96.6 (14.0)	102.9 (17.4)	104.8 (12.6)
KCO	99.7 (12.9)	101.8 (9.3)	90.9 (12.6)
$P_{D_{20}}$	195.2 (57.6)	195.2 (44.2)	167.3 (72.7)

Twelve subjects were in each of the three subgroups. There were two positive bronchial challenges in the exposed farmer group, three positive challenges in the farmer control group, and four positive challenges in the normal control group. All groups were well within predicted limits and not significantly different from other groups (all p values were > 0.05 by *t* test analysis) for all of the values listed above. **Conclusion**: We conclude that farmers with previous episodes of ODTS do not have measurable differences in either pulmonary function or bronchial reactivity when compared to a similar farmer group without a history of ODTS or with matched controls who have never worked on a farm or been exposed to high levels of organic dust. (OF-90-029)

Positive Expiratory Pressure (PEP) Mask Therapy as a Bronchial Hygiene Technique—Michael Mahlmeister MS RRT, Gale Hoffman RRT, Lillian Fifer RRT. University of California Medical Center at San Francisco, *San Francisco, California.*

Positive expiratory pressure (PEP) mask therapy has been employed to facilitate the removal of bronchial secretions in pa-

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tients with pulmonary conditions that predispose to large-volume sputum production. PEP breathing augments both FRC and the distribution of ventilation, promoting a pressure gradient during exhalation that mobilizes secretions toward the central airways. PEP therapy can be self-administered using an anesthesia mask, one-way valve, variable expiratory resistor, and manometer. The patient sits upright and inspires a large tidal volume, followed by a 3-s breath-hold, then exhales through the resistor, generating a PEP of 10-20 cm H_2O. A series of 10 to 15 PEP breaths is performed, followed by 2 huff coughs (mask removed) to mobilize secretions. This sequence of PEP breaths and huff coughs is repeated 5 to 6 times, for a total therapy session of 15-20 minutes. **Case Summary**: A 3 1/2-year-old girl with cystic fibrosis was seen in the clinic with cough, bilateral rhonchi, and tachypnea. Home therapy orders included qid nebulized albuterol and cromolyn, followed by postural drainage and percussion. The parents reported their inability to perform regular, effective postural drainage and percussion, due to the child's restlessness and crying. During a PEP-training session, the child was able to perform 15 minutes of PEP, done in conjunction with her nebulizer treatment, raising 10 mL of sputum. The family received additional instructions and equipment for PEP home therapy. In each of 3 monthly follow-up clinic visits, the child was able to demonstrate proper PEP mask therapy, and the parents reported excellent compliance with qid home care. The child was eupneic, without cough or rhonchi on all 3 clinic visits. **Discussion**: This case illustrates the value of PEP therapy in pediatric patients when administered by parents or self-administered. We have utilized PEP therapy in a series of 10 pediatric patients (age 3 1/2-14 y). At 6-month follow-up, 9/10 patients continued regular PEP therapy, with sputum production ≥ that seen with postural drainage and percussion. PEP therapy is easy to perform, without the risks, inconvenience, time commitment, or non-compliance associated with postural drainage and percussion. **Conclusion**: On the basis of our initial experience, we will continue to instruct pediatric and adult patients in PEP mask therapy, and plan to pursue controlled clinical trials comparing PEP mask therapy to postural drainage and percussion. (OF-90-101)

Balloon Characteristics of Pulmonary Artery Catheters: Are They a Cause for Concern?—John M Palmisano RRT, Brad A Krauzowicz RRT, Jon N Meliones MD. University of Michigan Hospital, CS Mott Children's Hospital, *Ann Arbor, Michigan.*

The use of flow-directed pulmonary artery (PA) catheters is widely accepted. Depending upon the manufacturer and catheter size, 0.5 to 1.5 mL of air (preferrably CO_2) is routinely used to inflate the balloon. In clinical practice these catheters are repeatedly inflated, but complications of balloon inflation are not fully appreciated. We therefore evaluated the inflation characteristics of three types of commerically available pulmonary artery catheters (Arrow International, n = 6; American Edwards Laboratories, n = 6; Sorenson, n = 2) to determine specific balloon characteristics: diameter, length, and intraballoon pressure. **Method**: All catheters were tested in vitro using predetermined volumes of room temperature air ranging from the manufacturer-recommended volume to a maximum volume of 3.0 mL. All measurements were performed in triplicate. Intraballoon pressures were measured using a Sorenson Transpac II transducer, Honeywell VR 12, and Mingograf 7 physiologic recorder. **Results**:

Effect of Inflation Volume on PA-Catheter Balloon Characteristics

	% of Manufacturer-Recommended Inflation Volume				
Characteristics	100%	110%	120%	>120%	Max% Δ
Diameter (mm)	10.4	10.8	11.2	13.9	0.25
Length (mm)	8.4	9.0	9.6	14.8	0.43
Pressure (torr)	278	288	301	455	0.39

We found that a critical opening pressure of > 600 torr was necessary to unfold the balloon. Although this pressure had a tendency to dissipate after the balloon was opened, in one catheter very high intraballoon pressure developed that was significantly higher than that of the other catheters (488 ± 8.8 torr, Scheffe t test = 463). The data also indicated that inflations with volume ≤ 120% of the manufacturer-recommended volume lead to linear increases in diameter, length, and pressure, whereas volumes > 120% lead to an exponential increase in balloon length and balloon pressure. These findings are of particular importance in patients with pulmonary artery hypertension, in whom the pulmonary vasculature is much less compliant and may be subject to rupture during balloon inflation. Furthermore, these results indicate that by allowing both the length of the balloon and intraballoon pressure to increase, the increase in balloon diameter is limited. Frequently this overdistention of the balloon results in a dampened pressure reading. **Conclusions**: From these results we recommend: (1) limiting inflation volume of PA-catheter balloons to 120% of that recommended by the manufacturer; (2) utilizing the manufacturer-provided syringe because they are self-limiting and decrease the potential for overinflation; and (3) incorporating low-pressure balloons on pulmonary artery catheters, similiar to those used on endotracheal tubes. (OF-90-030)

Is It Cost-Effective to Utilize Overtime or Agency Personnel to Supplement Staffing—Judith A Weidman BA RN RRT, Robert M Lewis BA RRT. Children's Memorial Hospital, *Chicago, Illinois.*

Utilization of overtime and/or agency personnel (ie, supplementary personnel [SP]) is expensive. Hourly cost can be 1.5 to 3 times the cost of permanent personnel (PP). Regular use of SP may indicate a need for additional PP; however, use of SP may be more cost-effective than hiring additional PP if daily work load is highly variable. We developed a method for using records of supplementary staffing, based on objective productivity standards, to predict the need for additional PP. **Method**: We reviewed our department's SP utilization for a 1-year period. The number of shifts of SP used during the 1-year period, the average number of SP used/day, and the average number of SP used/shift were determined. Various simulated schedules were constructed with varying numbers of additional PP to determine the number of additional PP that would result in a bal-

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ance between reduction of SP during periods of peak work load and reduction of nonproductive PP time during periods of decreased work load. **Results**: 2,410 shifts of SP were utilized in a 12-mo period. This is the equivalent of 10.0 full-time equivalents (FTEs). Mean utilization was 2.0 SP/shift of SP utilization (6/day) (range 0-9/day); however, this was not evenly distributed each day or each shift. During the year, 160 shifts required no SP, while over 200 shifts required 5 or more SP. Schedule simulations showed that an additional 6 PP would reduce the use of higher-paid SP, while not incurring excessive cost due to unproductive PP time during periods of reduced work load. Replacing all 10 FTEs of SP with PP would have resulted in excessive staff capacity during periods of reduced work load, resulting in overall reduced productivity. **Conclusions**: Use of SP can be cost-effective in the presence of varying work loads. The optimum SP-to-PP ratio must be determined by analysis of staffing needs, based on objective productivity standards. (OF-90-151)

A Retrospective Study of the Effects of Flexible Employee Scheduling—Cynthia P Mizzell RRT. MUSC Medical Center, *Charleston, South Carolina.*

Flexible employee scheduling is a tool used by respiratory care department managers to improve employee recruitment, retention, absenteeism, and productivity. Eight months ago my department instituted a new, creative flexible schedule. Permanent employees are allowed to work either 8- or 12-hour shifts, depending on their personal needs. The minimum number of hours worked must equal the number they were hired to work. A temporary employee pool was started, and employees were made aware of vacancies in the schedule. In this retrospective study, I sought to compare 8 months of using the new schedule to the same 8 mo of the previous year when a conventional 8-h shift schedule was used. **Method**: The number of occasional sick days, full-time equivalent (FTE) vacancies, overtime hours, temporary-pool hours worked, and procedures performed during each 8-mo period was noted. The collected data were averaged for the two time periods. **Results**: Occasional sick days/month increased from 18.8 to 20.1. Permanant FTE vacancies decreased from 9 to 3, and there was a 6.2 FTE increase in the temporary employee pool. Overtime hours increased 97.2%, while procedures performed increased only 5%. **Conclusions**: The findings of this study suggest that flexible employee scheduling may have helped staff recruitment and retention. However, these positive benefits are outweighed by the negative effects of a marked increase in personnel hours worked without evidence of a comparable increase in productivity. Further evaluation and modification of this flexible scheduling process is needed. (OF-90-109)

Equipment Acquisition and Methodology

Portable Airway-Suction Systems: A Comparison of Performance—Robert M Kacmarek PhD RRT, John F Curran RRT, Kevin S Stanek BSEE. Massachusetts General Hospital, *Boston, Massachusetts.*

Numerous portable suction systems are available on the market. These systems are powered either manually, pneumatically, or electrically. We compared the performance of three electric systems (Laerdal Suction Unit and Laerdal Compact Suction Unit, Laerdal Medical, Armonk NY; and the Matrx Portable Suction Unit, Matrx Medical Inc, Orchard Park NY), and two manual systems (Emergency Aspirator, Vitalograph Medical Instrumentation, Lenexa KS; and V-VAC, California Medical Products, Long Beach CA) to wall suction set at a maximum setting of 300 torr. **Methods**: We measured the maximum pressure obtainable with each system; the volume of maple syrup suctioned within 5 seconds; and the time required to suction 150 mL of maple syrup. Five trials were performed for each measurement. **Results**:

Performance Comparison: Portable Suction Systems vs Wall Suction

	Performance Variables*		
Suction Systems	Maximum Pressure	Volume of Syrup/ 5 s of Suction	Suction Time/ 150 mL Syrup
Wall Suction	300	33.2 (3.6)	51.6 (6.9)
Laerdal Suction Unit	517 (3.5)†	24.4 (9.5)	56.6 (3.1)
Laerdal Compact Suction Unit	515 (0.0)†	42.8 (4.1)†	42.8 (2.3)
Matrx Portable Unit	466 (5.7)†	16.0 (4.9)†	50 (1.1)
Emergency Aspirator	283 (15.7)	20.0 (9.9)†	63.0 (3.8)†
V-VA	193 (9.4)†	9.2 (1.8)†	120†‡

*All values are mean (SD); pressure is in torr, volume in mL, and time in s.
†Significant difference compared to wall suction ($p < 0.05$, ANOVA).
‡Stopped after 2 min; 100 (7.3) mL of syrup suctioned.

Conclusion: Although statistically significant differences in performance were observed between the portable systems and wall suction, we do not think that clinically important differences exist. Even the California Medical V-VAC system, whose performance least resembled wall suction performance, proved capable of generating a maximum pressure that exceeds the standard suction pressure (120-150 torr) used in adults. (OF-90-141)

Clinical Comparison of the Trach Care and Steri-Cath Suction Catheters—Patricia A Doorley MS RRT, Charles G Durbin Jr MD, Warren D Nicholson RRT. University of Virginia Medical Center, *Charlottesville, Virginia.*

Closed-system suction catheters (CSSCs) have been introduced to eliminate the need for disconnecting patients from mechanical ventilatory support during endotracheal suctioning. We concurrently evaluated two brands of CSSC—the single-lumen Ballard Trach Care (Ballard Medical Products, Midvale UT) and the double-lumen Concord Steri-Cath (Concord Labs, Keene NH). The purpose of the study was to assess the clinical acceptability of each brand and to provide a basis for competitive price bidding. **Methods**: Twenty-five mechanically ventilated patients were suctioned with both catheters (459 procedures performed with 75 Ballard CSSCs and 499 procedures

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performed with 82 Concord CSSCs). (All CSSCs were size 14 Fr.) Heart rate, blood pressure, ECG, intracranial pressure (if appropriate), and S_{pO_2} were continuously monitored. A Ballard CSSC was placed in the ventilator circuit initially and then replaced by a Concord CSSC after 24 hours. The catheters were alternated every 24 hours until the patient was removed from the study. Each time a patient was suctioned, the caregiver scored the following parameters using either Yes (Y) or No (N): (1) effective secretion removal, (2) fall in S_{pO_2} to < 85%, (3) need to increase F_{IO_2} to 1.0, and (4) deterioration of vital signs (ie, heart rate, blood pressure, intracranial pressure, cardiac rhythm) and/or increased patient agitation. The parameter scores for the Ballard were compared to those for the Concord using chi-square analysis. **Results**:

Comparative Evaluation of CSSCs

	Ballard (Y/N)	Concord (Y/N)
Effective secretion removal	410/15*	430/47
Fall in S_{pO_2} to < 85%	32/427*	54/445
Need to increase F_{IO_2} to 1.0	43/416*	78/421
Deterioration of heart rate	70/389	42/457*
Deterioration of blood pressure	39/420	44/455
Deterioration of intracranial pressure	7/452	7/492
Increased cardiac dysrhythmias	6/453	2/497
Increased patient agitation	8/451	3/496

*Best-rated CSSC ($p < 0.05$, chi-square analysis).

Conclusion: Although statistically the Ballard Trach Care CSSC appeared to be superior to the Concord Steri-Cath CSSC, the small differences in the clinical findings suggested that both were clinically acceptable; and, therefore, competitive price bidding was used. (OF-90-128)

Evaluation of the Accuracy and Reusability of the Hamilton Medical Variable-Orifice Flowsensor—Robert S Campbell RRT, Richard D Branson RRT, James M Hurst MD. University of Cincinnati Medical Center, *Cincinnati, Ohio.*

The Hamilton Medical variable-orifice flowsensor (Hamilton Medical, Reno NV) is intended for single patient use. We designed a study to evaluate the accuracy and durability of the flowsensor after repeated use and cleaning. **Method**: We divided 36 flowsensors into 3 groups to designate the cleaning technique used: I (Control), II (Pasteurization), and III (Cidex). Initially all flowsensors were calibrated using a Hamilton Veolar, and accuracy was determined by comparing measured volume to an RT-200 calibration analyzer. Accuracy was assessed at three volumes (0.4, 0.8, 1.2 L) using three peak flowrates (0.5, 1.0, 1.5 L/s) and a decelerating flow pattern. Flowsensor use was simulated in the laboratory using a piston ventilator, heated humidifier, and test lung. Following each 48 hours of simulated use, any flowsensor that failed the calibration or measured < 90% or > 110% of the actual volume was eliminated from the study. An end point for the study was set at 16 uses and cleanings. **Results**: Seventeen (47%) flowsensors were removed from the study prior to the end point. One flowsensor in Group III was broken during removal from the test lung after one use. Only one flowsensor failed the Veolar flowsensor calibration prior to elimination from the study. The majority (88%) of flowsensors that were removed from the study measured volume inaccurately at the 1.5 L/s flowrate.

Flowsensor Group*	Flowsensor Failures	Average Number of Uses & Cleanings	Cost per Use**
I (Control)	3	14	$0.64
II (Pasteurization)	5	12	$0.75
III (Cidex)	9	7	$1.29

*n = 12 flowsensors/group.

**Based upon a cost of $9.00/flowsensor.

Discussion: Our study indicates that the Hamilton flowsensor will maintain accuracy following multiple uses and cleanings. No flowsensor in Group I or III showed any visual signs of damage as a result of use or cleaning. All Group II flowsensors were opacified because of the heat of pasteurization, which also noticeably softened the flowsensor tubing. Flowsensors in Group II maintained accuracy 42% longer than those in Group III. Flowsensor use, independent of cleaning technique, also appears to affect durability, evidenced by the fact that three Control (Group I) flowsensors were eliminated from the study. **Conclusions**: Our findings suggest that Hamilton flowsensors may be cleaned and reused multiple times if, in addition to the ventilator flowsensor calibration, accuracy is tested prior to clinical use. The reuse of flowsensors will reduce the operating expenses associated with all Hamilton ventilators. (OF-90-063)

Evaluation of Oxygen-Monitor Power-Supply Design Change—Wadie Williams RRT, John S Sabo MS RRT. St Luke's Episcopal Hospital, *Houston, Texas.*

Mechanically ventilated patients require continuous or periodic monitoring of F_{IO_2}. We performed a cost analysis of 60 Puritan-Bennett battery-operated oxygen monitors (Part No. 19715) over a 3-mo period. The focus of this analysis was expenditures associated with the purchase of disposable batteries during continuous O_2 monitoring. The average battery life in continuous use was 3 days. The projected annualized cost (PAC)/analyzer was $730 or 60.83 batteries/month; projected annualized fleet cost (AFC) was $43,800. An operational decision was made to use the monitors on an intermittent basis and to determine whether other cost-effective measures were available. A second cost analysis was performed over a 12-mo period. This analysis indicated a decrease in expenditures by 88.01%. The PAC/analyzer was $88.32 or 7.36 batteries/month; AFC was $5,299.20. Although financially successful, the inability to continuously monitor patients was not acceptable. A design change was proposed in the power supply system to allow continuous use via alternating current power with battery backup power. The conversion was planned, tested, and installed by hospital biomedical engineers. The cost of conversion was $6,000 (parts and labor). Although the conversion exceeded the intermittent use cost by 12%, there is a projected second year savings of 59% in operating cost (the second year's operating costs consist of an estimated $2,150 for extra

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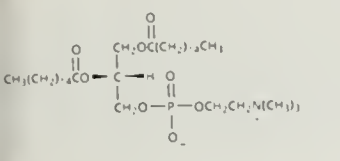

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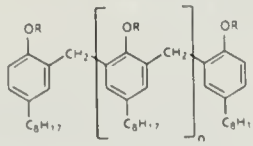
tyloxapol
(formaldehyde polymer with oxirane and 4-(1,1,3,3-tetramethylbutyl)phenol)



[R is $CH_2CH_2O(CH_2CH_2O)_mCH_2CH_2OH$, m is 6 to 8, n is not more than 5]

CLINICAL PHARMACOLOGY: Surfactant deficiency is an important factor in the development of the neonatal respiratory distress syndrome (RDS). Thus, surfactant replacement therapy early in the course of RDS should ameliorate the disease and improve symptoms. Natural surfactant, a combination of lipids and apoproteins, exhibits not only surface tension reducing properties (conferred by the lipids), but also rapid spreading and adsorption (conferred by the apoproteins). The major fraction of the lipid component of natural surfactant is DPPC, which comprises up to 70% of natural surfactant by weight. Although DPPC reduces surface tension, DPPC alone is ineffective in RDS because DPPC spreads and adsorbs poorly. In Exosurf Neonatal, which is protein free, cetyl alcohol acts as the spreading agent for the DPPC on the air-fluid interface. Tyloxapol, a polymeric long-chain repeating alcohol, is a nonionic surfactant which acts to disperse both DPPC and cetyl alcohol. Sodium chloride is added to adjust osmolality.

Pharmacokinetics: Exosurf Neonatal is administered directly into the trachea. Human pharmacokinetic studies of the absorption, biotransformation, and excretion of the components of Exosurf Neonatal have not been performed. Nonclinical studies, however, have shown that DPPC can be absorbed from the alveolus into lung tissue where it can be catabolized extensively and reutilized for further phospholipid synthesis and secretion. In the developing rabbit, 90% of alveolar phospholipids are recycled. In premature rabbits, the alveolar half-life of intratracheally administered H^3-labeled phosphatidylcholine is approximately 12 hours.

Animal Studies: In animal models of RDS, treatment with Exosurf Neonatal significantly improved lung volume, compliance and gas exchange in premature rabbits and lambs. The amount and distribution of lung water were not affected by Exosurf. Neonatal treatment of premature rabbit pups. The extent of lung injury in premature rabbit pups undergoing mechanical ventilation was reduced significantly by Exosurf Neonatal treatment. In premature lambs, neither systemic blood flow nor flow through the ductus arteriosus were affected by Exosurf Neonatal treatment. Survival was significantly better in both premature rabbits and premature lambs treated with Exosurf Neonatal.

Clinical Studies: Exosurf Neonatal has been studied in the U.S. and Canada in controlled clinical trials involving more than 4400 infants. Over 10,000 infants have received Exosurf Neonatal through an open, uncontrolled, North American study designed to provide the drug to premature infants who might benefit and to obtain additional safety information (Exosurf Neonatal Treatment IND).

Prophylactic Treatment: The efficacy of a single dose of Exosurf Neonatal in prophylactic treatment of infants at risk of developing respiratory distress syndrome (RDS) was examined in three double-blind, placebo-controlled studies, one involving 215 infants weighing 500 to 700 grams, one involving 385 infants weighing 700 to 1350 grams, and one involving 446 infants weighing 700 to 1100 grams. The infants were intubated and placed on mechanical ventilation, and received 5 mL/kg Exosurf Neonatal or placebo (air) within 30 minutes of birth.

The efficacy of one versus three doses of Exosurf Neonatal in prophylactic treatment of infants at risk of developing RDS was examined in a double-blind, placebo-controlled study of 823 infants weighing 700 to 1100 grams. The infants were intubated and placed on mechanical ventilation, and received a first 5 mL/kg dose of Exosurf Neonatal within 30 minutes. Repeat 5 mL/kg doses of Exosurf Neonatal or placebo (air) were given to all infants who remained on mechanical ventilation at approximately 12 and 24 hours of age. An initial analysis of 716 infants is available.

The major efficacy parameters from these studies are presented in Table 1.

Table 1 — **Efficacy Assessments—Prophylactic Treatment**

Number of Doses / Birth Weight Range	Single Dose 500 to 700 grams		Single Dose 700 to 1350 grams		Single Dose 700 to 1100 grams		One Versus Three Doses 700 to 1100 grams	
Treatment Group / Number of Infants	Placebo (Air) N=106	EXOSURF N=109	Placebo (Air) N=185	EXOSURF N=176	Placebo (Air) N=222	EXOSURF N=224	One EXOSURF Dose N=356	Three EXOSURF Doses N=360
	% of Infants		% of Infants		% of Infants		% of Infants	
Death ≤ Day 28[a]	53	50	11	6	21	15	16	9*
Death through 1 Year[a]	59	60	14	11	30	20**	17	12*
Death from RDS[b]	25	13*	4	3	10	5§	3	2
Intact Cardiopulmonary Survival[a,c]	29	25	69	78*	65	68	74	78
Bronchopulmonary Dysplasia (BPD)[a,d]	43	44	23	18	19	21	8	12
RDS Incidence[b]	73	81	46	42	55	55	63	68

[a] "Intent-to-treat" analyses (as randomized) except for the 700 to 1350 gram, single dose study in which patients with congenital infections and anomalies were excluded.
[b] "As-treated" analyses.
[c] Defined by survival through 28 days of life without bronchopulmonary dysplasia.
[d] Defined by a combination of clinical and radiographic criteria.
* $p<0.05$
** $p<0.01$
§ $p=0.051$

Rescue Treatment: The efficacy of Exosurf Neonatal in the rescue treatment of infants with RDS was examined in two double-blind, placebo-controlled studies. One study enrolled 419 infants weighing 700 to 1350 grams, the second enrolled 1237 infants weighing 1250 grams and above. In the rescue treatment studies, infants received an initial dose (5 mL/kg) of Exosurf Neonatal or placebo (air) between 2 and 24 hours of life followed by a second dose (5 mL/kg) approximately 12 hours later to infants who remained on mechanical ventilation. The major efficacy parameters from these studies are presented in Table 2.

Table 2 — **Efficacy Assessments—Rescue Treatment**

Number of Doses / Birth Weight Range	Two Doses 700 to 1350 grams		Two Doses 1250 grams and above	
Treatment Group / Number of Infants	Placebo (Air) N=213	EXOSURF N=206	Placebo (Air) N=623	EXOSURF N=614
	% of Infants		% of Infants	
Death ≤ Day 28[a]	23	11***	7	4*
Death through 1 Year[a]	27	15***	9	6§
Death from RDS[b]	10	3**	3	1*
Intact Cardiopulmonary Survival[a,c]	62	75**	88	93**
Bronchopulmonary Dysplasia (BPD)[a,d]	18	15	6	3*

[a] "Intent-to-treat" analyses (as randomized)
[b] "As-treated" analyses
[c] Defined by survival through 28 days of life without bronchopulmonary dysplasia
[d] Defined by a combination of clinical and radiographic criteria
* $p<0.05$
** $p<0.01$
*** $p<0.001$
§ $p=0.067$

Clinical Results: In these six controlled clinical studies, infants in the Exosurf Neonatal group showed significant improvements in FiO_2 and ventilator settings which persisted for at least 7 days. Pulmonary air leaks were significantly reduced in each study. Five of these studies also showed a significant reduction in death from RDS. Further, overall mortality was reduced for all infants weighing >700 grams. The one versus three-dose prophylactic treatment study in 700 to 1100 gram infants showed a further reduction in overall mortality with two additional doses.

Safety information is presented in Tables 3 and 4 (see ADVERSE REACTIONS). Beneficial effects in the Exosurf Neonatal group were observed for some safety assessments. Various forms of pulmonary air leak and use of pancuronium were reduced in infants receiving Exosurf Neonatal in all six studies.

Follow-up data at one year adjusted age are available on 1094 of 2470 surviving infants. Growth and development of infants who received Exosurf Neonatal in this sample were comparable to infants who received placebo.

INDICATIONS AND USAGE: Exosurf Neonatal is indicated for:

1. **Prophylactic** treatment of infants with birth weights of less than 1350 grams who are at risk of developing RDS (see PRECAUTIONS).
2. **Prophylactic** treatment of infants with birth weights greater than 1350 grams who have evidence of pulmonary immaturity, and
3. **Rescue** treatment of infants who have developed RDS.

For **prophylactic** treatment, the first dose of Exosurf Neonatal should be administered as soon as possible after birth (see DOSAGE AND ADMINISTRATION, General Guidelines for Administration).

Infants considered as candidates for **rescue** treatment with Exosurf Neonatal should be on mechanical ventilation and have a diagnosis of RDS by both of the following criteria:

1. Respiratory distress not attributable to causes other than RDS, based on clinical and laboratory assessments
2. Chest radiographic findings consistent with the diagnosis of RDS

During the clinical development of Exosurf Neonatal, all infants who received the drug were intubated and on mechanical ventilation. For three-dose prophylactic treatment with Exosurf Neonatal, the first dose of drug was administered as soon as possible after birth and repeat doses were given at approximately 12 and 24 hours after birth if infants remained on mechanical ventilation at those times. For rescue treatment, two doses were given, one between 2 and 24 hours of life, and a second approximately 12 hours later if infants remained on mechanical ventilation. Infants who received rescue treatment with Exosurf Neonatal had a documented arterial to alveolar oxygen tension ratio (a/A) <0.22.

CONTRAINDICATIONS: There are no known contraindications to treatment with Exosurf Neonatal.

WARNINGS:

Intratracheal Administration Only: Exosurf Neonatal should be administered only by instillation into the trachea (see DOSAGE AND ADMINISTRATION).

General:

The use of Exosurf Neonatal requires expert clinical care by experienced neonatologists and other clinicians who are accomplished at neonatal intubation and ventilatory management. Adequate personnel, facilities, equipment, and medications are required to optimize perinatal outcome in premature infants.

Instillation of Exosurf Neonatal should be performed **only** by trained medical personnel experienced in airway and clinical management of unstable premature infants. Vigilant clinical attention should be given to all infants prior to, during, and after administration of Exosurf Neonatal.

Acute Effects: Exosurf Neonatal can rapidly affect oxygenation and lung compliance.

Lung Compliance: If chest expansion improves substantially after dosing, peak ventilator inspiratory pressures should be reduced immediately, without waiting for confirmation of respiratory improvement by blood gas assessment. Failure to reduce inspiratory ventilator pressures rapidly in such instances can result in lung overdistention and fatal pulmonary air leak.

Hyperoxia: If the infant becomes pink and transcutaneous oxygen saturation is in excess of 95%, FiO_2 should be reduced in small but repeated steps (until saturation is 90 to 95%) without waiting for confirmation of elevated arterial pO_2 by blood gas assessment. Failure to reduce FiO_2 in such instances can result in hyperoxia.

Hypocarbia: If arterial or transcutaneous CO_2 measurements are <30 torr, the ventilator rate should be reduced at once. Failure to reduce ventilator rates in such instances can result in marked hypocarbia, which is known to reduce brain blood flow.

Pulmonary Hemorrhage: In the single study conducted in infants weighing <700 grams at birth, the incidence of pulmonary hemorrhage (10% vs 2% in the placebo group) was significantly increased in the Exosurf Neonatal group. None of the five studies involving infants with birth weights >700 grams showed a significant increase in pulmonary hemorrhage in the Exosurf Neonatal group. In a cross-study analysis of these five studies, pulmonary hemorrhage was reported for 1% (14/1420) of infants in the placebo group and 2% (27/1411) of infants in the Exosurf Neonatal group. Fatal pulmonary hemorrhage occurred in three infants; two in the Exosurf Neonatal group and one in the placebo group. Mortality from all causes among infants who developed pulmonary hemorrhage was 43% in the placebo group and 37% in the Exosurf Neonatal group.

Pulmonary hemorrhage in both Exosurf Neonatal and placebo infants was more frequent in infants who were younger, smaller, male, or who had a patent ductus arteriosus. Pulmonary hemorrhage typically occurred in the first 2 days of life in both treatment groups.

In more than 7700 infants in the open, uncontrolled study, pulmonary hemorrhage was reported in 4%, but fatal pulmonary hemorrhage was reported rarely (0.4%).

In the controlled clinical studies, Exosurf Neonatal treated infants who received steroids more than 24 hours prior to delivery or indomethacin postnatally had a lower rate of pulmonary hemorrhage than other Exosurf Neonatal treated infants. Attention should be paid to early and aggressive diagnosis and treatment (unless contraindicated) of patent ductus arteriosus during the first 2 days of life (while the ductus arteriosus is often clinically silent). Other potentially protective measures include attempting to decrease FiO_2 preferentially over ventilator pressures during the first 24 to 48 hours after dosing, and attempting to decrease PEEP minimally for at least 48 hours after dosing.

Mucous Plugs: Infants whose ventilation becomes markedly impaired during or shortly after dosing may have mucous plugging of the endotracheal tube, particularly if pulmonary secretions were prominent prior to drug administration. Suctioning of all infants prior to dosing may lessen the chance of mucous plugs obstructing the endotracheal tube. If endotracheal tube obstruction from such plugs is suspected, and suctioning is unsuccessful in removing the obstruction, the blocked endotracheal tube should be replaced immediately.

PRECAUTIONS:

General: In the controlled clinical studies, infants known prenatally or postnatally to have major congenital anomalies, or who were suspected of having congenital infection, were excluded from entry. However, these disorders cannot be recognized early in life in all cases, and a few infants with these conditions were entered. The benefits of Exosurf Neonatal in the affected infants who received drug appeared to be similar to the benefits observed in infants without anomalies or occult infection.

Prophylactic Treatment–Infants <700 Grams: In infants weighing 500 to 700 grams, a single prophylactic dose of Exosurf Neonatal significantly improved FiO_2 and ventilator settings, reduced pneumothorax, and reduced death from RDS, but increased pulmonary hemorrhage (see WARNINGS). Overall mortality did not differ significantly between the placebo and Exosurf Neonatal groups (see Table 1). Data on multiple doses in infants in this weight class are not yet available. Accordingly, clinicians should carefully evaluate the potential risks and benefits of Exosurf Neonatal administration in these infants.

Rescue Treatment–Number of Doses: A small number of infants with RDS have received more than two doses of Exosurf Neonatal as rescue treatment. Definitive data on the safety and efficacy of these additional doses are not available.

Carcinogenesis, Mutagenesis, Impairment of Fertility: Exosurf Neonatal at concentrations up to 10,000 µg/plate was not mutagenic in the Ames Salmonella assay.

Long-term studies have not been performed in animals to evaluate the carcinogenic potential of Exosurf Neonatal.

The effects of Exosurf Neonatal on fertility have not been studied.

ADVERSE REACTIONS:

General: Premature birth is associated with a high incidence of morbidity and mortality. Despite significant reductions in overall mortality associated with Exosurf Neonatal, some infants who received Exosurf Neonatal developed severe complications and either survived with permanent handicaps or died.

In controlled clinical studies evaluating the safety and efficacy of Exosurf Neonatal, numerous safety assessments were made. In infants receiving Exosurf Neonatal, pulmonary hemorrhage, apnea and use of methylxanthines were increased. A number of other adverse events were significantly reduced in the Exosurf Neonatal group, particularly various forms of pulmonary air leak and use of pancuronium. (See CLINICAL PHARMACOLOGY, Clinical Results.) Tables 3 and 4 summarize the results of the major safety evaluations from the controlled clinical studies.

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Table 3 **Safety Assessments[a]—Prophylactic Treatment**

Number of Doses: Birth Weight Range	Single Dose 500 to 700 grams		Single Dose 700 to 1350 grams		Single Dose 700 to 1100 grams		One Versus Three Doses 700 to 1100 grams	
Treatment Group Number of Infants	Placebo (Air) N=108	EXOSURF N=107	Placebo (Air) N=193	EXOSURF N=192	Placebo (Air) N=222	EXOSURF N=224	One EXOSURF Dose N=356	Three EXOSURF Doses N=360
	% of Infants		% of Infants		% of Infants		% of Infants	
Intraventricular Hemorrhage (IVH)								
Overall	51	57	31	27	36	36	38	35
Severe IVH	26	25	10	8	13	14	9	9
Pulmonary Air Leak (PAL)								
Overall	52	48	16	11	32	25	29	27
Pneumothorax	23	10*	5	6	19	11*	14	12
Pneumopericardium	1	4	2	0	<1	1	1	1
Pneumomediastinum	2	1	2	3	7	1**	3	2
Pulmonary Interstitial Emphysema	43	44	13	7*	26	20	23	22
Death from PAL	4	6	<1	<1	2	1	2	1
Patent Ductus Arteriosus	49	53	66	70	50	55	59	57
Necrotizing Enterocolitis	2	4	11	13	3	4	6	2*
Pulmonary Hemorrhage	2	10**	2	4	1	4	4	6
Congenital Pneumonia	4	4	2	4	2	2	1	1
Nosocomial Pneumonia	10	10	2	4	4	7	14	15
Non-Pulmonary Infections	33	35	34	39	28	29	35	34
Sepsis	30	34	30	34	23	24	30	27
Death From Sepsis	4	4	3	3	1	2	3	2
Meningitis	4	6	3	1	2	3	1	2
Other Infections	7	4	5	3	6	10	10	11
Major Anomalies	3	1	2	4	7	4	4	4
Hypotension	70	77	52	47	59	62	54	50
Hyperbilirubinemia	22	21	63	61	27	31	20	21
Exchange Transfusion	4	3	1	2	2	2	3	1
Thrombocytopenia[b]	21	25	not available		9	8	12	10
Persistent Fetal Circulation	0	1	1	1	0	2*	1	<1
Seizures	11	8	2	2	11	9	6	5
Apnea	34	33	76	73	55	65*	62	68
Drug Therapy								
Antibiotics	96	99	98	96	98	99	>99	99
Diuretics	55	60	39	37	59	63	64	65
Anticonvulsants	14	18	23	24	20	16	9	8
Inotropes	46	40	20	20	26	20	28	27
Sedatives	62	71	65	64	63	57	52	52
Pancuronium	19	11	22	14*	19	13*	15	11
Methylxanthines	38	43	77	77	61	72*	75	82*

[a] All parameters were examined with "as-treated" analyses.
[b] Thrombocytopenia requiring platelet transfusion.

* p<0.05
** p<0.01

Table 4 **Safety Assessments[a]—Rescue Treatment**

Number of Doses: Birth Weight Range:	Two Doses 700 to 1350 grams		Two Doses 1250 grams and above	
Treatment Group Number of Infants:	Placebo (Air) N=213	EXOSURF N=206	Placebo (Air) N=622	EXOSURF N=615
	% of Infants		% of Infants	
Intraventricular Hemorrhage (IVH)				
Overall	48	52	23	18*
Severe IVH	13	9	5	4
Pulmonary Air Leak (PAL)				
Overall	54	34***	30	18***
Pneumothorax	29	20*	20	10***
Pneumopericardium	4	1	1	2
Pneumomediastinum	8	4	5	2**
Pulmonary Interstitial Emphysema	48	25***	24	13***
Death from PAL	7	3	<1	1
Patent Ductus Arteriosus	66	57	54	45*
Necrotizing Enterocolitis	3	3	1	2
Pulmonary Hemorrhage	3	1	<1	1
Congenital Pneumonia	2	3	2	2
Nosocomial Pneumonia	5	7	2	2
Non-Pulmonary Infections	19	22	13	13
Sepsis	15	17	8	8
Death From Sepsis	<1	<1	1	<1
Meningitis	1	<1	1	<1*
Other Infections	5	8	5	6
Major Anomalies	3	3	4	4
Hypotension	62	57	50	39**
Hyperbilirubinemia	17	19	12	10
Exchange Transfusion	3	4	1	2
Thrombocytopenia[b]	10	11	4	<1**
Persistent Fetal Circulation	1	1	6	2**
Seizures	10	10	6	3*
Apnea	48	65**	37	44*
Drug Therapy				
Antibiotics	100	99	98	98
Diuretics	60	65	45	34***
Anticonvulsants	17	17	10	5**
Inotropes	36	31	27	16***
Sedatives	72	68	76	64***
Pancuronium	34	17**	33	15***
Methylxanthines	62	74**	49	53

[a] All parameters were examined with "as-treated" analyses.
[b] Thrombocytopenia requiring platelet transfusion

* p<0.05
** p<0.01
*** p<0.001

Pulmonary Hemorrhage: See WARNINGS

Abnormal Laboratory Values: Abnormal laboratory values are common in critically ill, mechanically ventilated, premature infants. A higher incidence of abnormal laboratory values in the Exosurf Neonatal group was not reported.

Events During Dosing: Data on events during dosing are available from more than 8800 infants in the open, uncontrolled clinical study (Table 5).

Table 5 **Events During Dosing in the Open, Uncontrolled Study[a]**

Treatment Type: Number of Infants:	Prophylactic Treatment N=1127	Rescue Treatment N=7711
	% of Infants	% of Infants
Reflux of Exosurf	20	31
Drop in O_2 saturation (≥ 20%)	6	22
Rise in O_2 saturation (≥ 10%)	5	6
Drop in transcutaneous pO_2 (≥ 20 mm Hg)	1	8
Rise in transcutaneous pO_2 (≥ 20 mm Hg)	2	5
Drop in transcutaneous pCO_2 (≥ 20 mm Hg)	<1	1
Rise in transcutaneous pCO_2 (≥ 20 mm Hg)	1	3
Bradycardia (<60 beats/min)	1	3
Tachycardia (>200 beats/min)	<1	<1
Gagging	1	5
Mucous Plugs	<1	<1

[a] Infants may have experienced more than one event.
Investigators were prohibited from adjusting FiO_2 and/or ventilator settings during dosing unless significant clinical deterioration occurred.

Reflux: Reflux of Exosurf Neonatal into the endotracheal tube during dosing has been observed and may be associated with rapid drug administration. If reflux occurs, drug administration should be halted and, if necessary, peak inspiratory pressure on the ventilator should be increased by 4 to 5 cm H_2O until the endotracheal tube clears.

>20% Drop in Transcutaneous Oxygen Saturation: If transcutaneous oxygen saturation declines during dosing, drug administration should be halted and, if necessary, peak inspiratory pressure on the ventilator should be increased by 4 to 5 cm H_2O for 1 to 2 minutes. In addition, increases of FiO_2 may be required for 1 to 2 minutes.

Mucous Plugs: See WARNINGS

OVERDOSAGE: There have been no reports of massive overdosage with Exosurf Neonatal.

DOSAGE AND ADMINISTRATION:

Preparation of Suspension: Exosurf Neonatal is best reconstituted immediately before use because it does not contain antibacterial preservatives. However, the reconstituted suspension is chemically and physically stable when stored at 2° to 30°C (36° to 86°F) for up to 12 hours following reconstitution.

Solutions containing buffers or preservatives should not be used for reconstitution. **Do Not Use Bacteriostatic Water for Injection, USP.** Each vial of Exosurf Neonatal should be reconstituted only with 8 mL of the accompanying diluent (preservative-free Sterile Water for Injection) as follows: **1.** Fill a 10 mL or 12 mL syringe with 8 mL preservative-free Sterile Water for Injection using an 18 or 19 gauge needle, **2.** Allow the vacuum in the vial to draw the sterile water into the vial, **3.** Aspirate as much as possible of the 8 mL out of the vial into the syringe (while maintaining the vacuum), then SUDDENLY release the syringe plunger.

Step 3 should be repeated three or four times to assure adequate mixing of the vial contents. If vacuum is not present, the vial of Exosurf Neonatal should not be used.

The appropriate dosage volume for the entire dose (5 mL/kg) should then be drawn into the syringe from **below** the froth in the vial (again maintaining the vacuum). If the infant weighs less than 1600 grams, unused Exosurf Neonatal suspension will remain in the vial after the entire dose is drawn into the syringe. If the infant weighs more than 1600 grams, at least two vials will be required for each dose.

Reconstituted Exosurf Neonatal is a milky white suspension with a total volume of 8 mL per vial. Each mL of reconstituted Exosurf Neonatal contains 13.5 mg colfosceril palmitate, 1.5 mg cetyl alcohol, 1 mg tyloxapol, and sodium chloride to provide a 0.1 N concentration. If the suspension appears to separate, gently shake or swirl the vial to resuspend the preparation. The reconstituted product should be inspected visually for homogeneity immediately before administration; if persistent large flakes or particulates are present, the vial should not be used.

Dosage: Accurate determination of weight at birth is the key to accurate dosing.

Prophylactic Treatment: The first dose of Exosurf Neonatal should be administered as a single 5 mL/kg dose as soon as possible after birth. Second and third doses should be administered approximately 12 and 24 hours later to all infants who remain on mechanical ventilation at those times.

Rescue Treatment: Exosurf Neonatal should be administered in two 5 mL/kg doses. The initial dose should be administered as soon as possible after the diagnosis of RDS is confirmed. The second dose should be administered approximately 12 hours following the first dose, provided the infant remains on mechanical ventilation. A small number of infants with RDS have received more than two doses of Exosurf Neonatal as rescue treatment. Definitive data on the safety and efficacy of these additional doses are not available (see PRECAUTIONS).

Use of Special Endotracheal Tube Adapter: With each vial of Exosurf Neonatal Intratracheal Suspension, five different sized endotracheal tube adapters each with a special right angle Luer ®-lock sideport are supplied. The adapters are clean but not sterile. The adapters should be used as follows: **1.** Select an adapter size which corresponds to the inside diameter of the endotracheal tube. **2.** Insert the adapter into the endotracheal tube with a firm push-twist motion. **3.** Connect the breathing circuit wye to the adapter. **4.** Remove the cap from the sideport on the adapter. Attach the syringe containing drug to the sideport. **5.** After completion of dosing, remove the syringe and RECAP THE SIDEPORT.

Administration: The infant should be suctioned prior to administration of Exosurf Neonatal.

Exosurf Neonatal suspension is administered via the sideport on the special endotracheal tube adapter **WITHOUT INTERRUPTING MECHANICAL VENTILATION.**

Each Exosurf Neonatal dose is administered in two 2.5 mL/kg half-doses. Each half-dose is instilled slowly over 1 to 2 minutes (30 to 50 mechanical breaths) in small bursts timed with inspiration. After the first 2.5 mL/kg half-dose is administered in the midline position, the infant's head and torso are turned 45° to the **right** for 30 seconds while mechanical ventilation is continued. After the infant is returned to the midline position, the second 2.5 mL/kg half-dose is given in an identical fashion over another 1 to 2 minutes. The infant's head and torso are then turned 45° to the **left** for 30 seconds while mechanical ventilation is continued, and the infant is then turned back to the midline position. These maneuvers allow gravity to assist in the distribution of Exosurf Neonatal in the lungs.

During dosing, heart rate, color, chest expansion, facial expressions, the oximeter, and the endotracheal tube patency and position should be monitored. If heart rate slows, the infant becomes dusky or agitated, transcutaneous oxygen saturation falls more than 15%, or Exosurf Neonatal backs up in the endotracheal tube, dosing should be slowed or halted and, if necessary, the peak inspiratory pressure, ventilator rate, and/or FiO_2 turned up. On the other hand, rapid improvements in lung function may require immediate reductions in peak inspiratory pressure, ventilator rate, and/or FiO_2. (See WARNINGS and see below for additional information concerning administration.)

Suctioning should not be performed for two hours after Exosurf Neonatal is administered, except when dictated by clinical necessity.

General Guidelines for Administration: Administration of Exosurf Neonatal should not take precedence over clinical assessment and stabilization of critically ill infants.

Intubation: Prior to dosing with Exosurf Neonatal, it is important to ensure that the endotracheal tube tip is in the trachea and not in the esophagus or right or left mainstem bronchus. Brisk and symmetrical chest movement with each mechanical inspiration should be confirmed prior to dosing, as should equal breath sounds in the two axillae. In prophylactic treatment, dosing with Exosurf Neonatal need not be delayed for radiographic confirmation of the endotracheal tube tip position. In rescue treatment, bedside confirmation of endotracheal tube tip position is usually sufficient, if at least one chest radiograph subsequent to the last intubation confirmed proper position of the endotracheal tube tip. Some lung areas will remain undosed if the endotracheal tube tip is too low.

Monitoring: Continuous ECG and transcutaneous oxygen saturation monitoring during dosing are essential. In most infants treated prophylactically, it should be possible to initiate such monitoring prior to administration of the first dose of Exosurf Neonatal. For subsequent prophylactic and all rescue doses, arterial blood pressure monitoring during dosing is also highly desirable. After both prophylactic and rescue dosing, frequent arterial blood gas sampling is required to prevent post-dosing hyperoxia and hypocarbia (see WARNINGS).

Ventilatory Support During Dosing: The 5 mL/kg dosage volume may cause transient impairment of gas exchange by physical blockage of the airway, particularly in infants on low ventilator settings. As a result, infants may exhibit a drop in oxygen saturation during dosing, especially if they are on low ventilator settings prior to dosing. These transient effects are easily overcome by increasing peak inspiratory pressure on the ventilator by 4 to 5 cm H_2O for 1 to 2 minutes during dosing. FiO_2 can also be increased if necessary. In infants who are particularly fragile or reactive to external stimuli, increasing peak inspiratory pressure by 4 to 5 cm H_2O and/or FiO_2 20% just prior to dosing may minimize any transient deterioration in oxygenation. However, in virtually all cases it should be possible to return the infant to pre-dose settings within a very short time of dose completion.

Post-Dosing: At the end of dosing, position of the endotracheal tube should be confirmed by listening for equal breath sounds in the two axillae. Attention should be paid to chest expansion, color, transcutaneous saturation, and arterial blood gases. Some infants who receive Exosurf Neonatal and other surfactants respond with rapid improvements in pulmonary compliance, minute ventilation, and gas exchange (see WARNINGS). Constant bedside attention of an experienced clinician for at least 30 minutes after dosing is essential. Frequent blood gas sampling also is absolutely essential. Rapid changes in lung function require immediate changes in peak inspiratory pressure, ventilator rate, and/or FiO_2.

HOW SUPPLIED: Exosurf Neonatal for Intratracheal Suspension is supplied in a carton containing one 10 mL vial of Exosurf Neonatal for Intratracheal Suspension, one 10 mL vial of Sterile Water for Injection, and five endotracheal tube adapters (2.5, 3.0, 3.5, 4.0, and 4.5 mm). (NDC 0081-0207-01)

Store Exosurf Neonatal for Intratracheal Suspension at 15° to 30°C (59° to 86°F) in a dry place.

EDUCATIONAL MATERIAL: A videotape on dosing is available from your Burroughs Wellcome Co. representative. This videotape demonstrates techniques for safe administration of Exosurf Neonatal and should be viewed by health care professionals who will administer the drug.

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rechargeable batteries and chargers). For continuous monitor use, conversion payoff occurs in about 2 months. **Conclusion**: The power-supply system design change has enhanced the quality and cost-effectiveness of the patient care that we provide, by enabling us to provide continuous oxygen monitoring at a lower cost. We suggest that similar, safe changes should be used (pending necessary institutional approval and review of industry standards) to determine if O_2 monitors should have a dual power source. (OF-90-059)

Benefits of Interfacing Blood Gas Analyzers with an Information System—Thomas H Adkins BS RRT. Presbyterian Hospital of Dallas, *Dallas, Texas.*

A Respiratory Care Information System (RCIS) was implemented in the Pulmonary Services Department of my hospital to reduce documentation time and improve revenue capture. Prior to RCIS implementation, RCPs performing arterial blood gas (ABG) analysis were required to manually record ABG results, report results to the respective nursing unit, and enter results into a personal computer that generated an interpretation. This reporting and recording process required 5 minutes of RCP time per sample and an unspecified amount of nursing time. An average of 4,300 ABG analyses are performed per month at the hospital. The amount of RCP time required to perform this reporting and recording process was equivalent to 2.06 FTEs at an annual cost of approximately $38,500. Sixty percent of the ABG analyses required manual billing for an additional 0.19 FTEs and $1,975 in cost. Revenue was lost if ABG analyses were not documented or identified correctly. Retrieval of lost results or data from previous days or past admissions required looking through ABG log sheets. Documentation in the medical record consisted of a handwritten log and the ABG interpretation. A Cerner MedNet System was interfaced with the hospital information system (HIS) and the blood gas analyzers (BGA). When an ABG analysis is performed, data are transmitted from the BGA to the user's terminal for data verification and entry of pulmonary variables. Upon completion, ABG results are automatically posted in the RCIS, transmitted to the HIS, and printed at the nursing station; billing is registered and the interpretation is generated automatically. Daily reports are produced with all of a patient's ABG data and pulmonary information since admission. Reports are delivered by system operators equivalent to the 0.19 FTE previously allocated for billing. All current admission data are available in the RCIS or HIS, and results from past admissions have been stored for easy access. The cost of interfacing the Cerner MedNet System to 5 BGAs was $22,500 for hardware and interface software; an additional $2,400 is required annually for interface software support. A savings of $13,600 was realized the first year and subsequent year's savings are near $35,000. RCP time previously spent to document ABG analyses is directed toward patient care and new services. **Conclusion**: The RCIS has proved successful in reducing documentation and personnel time associated with ABG analysis, while making ABG data more accessible. RCP time previously spent on ABG documentation is now directed toward meeting existent patient care needs and developing new services. (OF-90-053)

Evaluation of Seven Low-Range Oxygen Flowmeters—Thomas A Barnes EdD RRT, Northeastern University; Mary Beth Donahoe CRTT, New England Medical Center—*Boston, Massachusetts.*

The use of accurate flowmeters is a prerequisite for safe delivery of oxygen therapy. When administering supplemental oxygen by nasal cannula to neonates, it is important that the flow be accurately controlled so that the P_{aO_2} remains within an acceptable range. Fluctuation of oxygen flow may result in inadequate oxygen delivery (which may cause hypoxia) or excessive oxygen delivery (which may contribute to bronchopulmonary dysplasia or lung toxicity). The accuracy of flowmeters used to deliver oxygen to adults (range of 0-15 L/min) has been reported to vary by 20-30%. The purpose of this study was to evaluate the accuracy of seven new flowmeters suitable for delivery of very low oxygen flow to neonates. The devices studied were: (1) Mada Medical Products Thorpe tube with pressure regulator and pin-indexed-inlet connector (range 0.125-3.0 L/min) (Mada Medical, Carlstadt NJ), (2) Timeter Classic 1000 Thorpe tube with standard valve-inlet connector (range 0.1-1.0 L/min) (The Timeter Group, Lancaster PA), (3) Timeter Classic 200 Thorpe tube with standard valve-inlet connector (range 0.025-0.200 L/min), (4) Veriflo Bourdon gauge with pin-indexed-inlet connector (0.125-0.5 L/min) (Veriflo, Richmond CA), (5) Mada Thorpe tube with pin-indexed-inlet connector (0.125-3.5 L/min), (6) Erie Medical Bourdon gauge with pin-indexed-inlet connector (1.0-8.0 L/min) (Erie Medical, Milwaukee WI), and (7) Ambu Orifice flow regulator with pin-indexed-inlet connector (0.25-25.0 L/min) (Ambu Inc, Hanover MD). **Method**: The accuracy of each flowmeter was studied by comparing preset flow to actual flow, using a Timeter RT200 Calibration Analyzer. The flow was measured with a 72-inch small-bore delivery tube attached to the flowmeter outlet. Several settings between 0.25 and 3.0 L/min were studied, dependent on the range of the flowmeter. Each run was repeated 5 times, and mean (SD) actual flow was determined. **Results**: The preset flow correlated with actual flow ($r = 1.00$) for all seven flowmeters. The flowmeters were variably accurate around the preset value, with a low error range of 0.1-6.0 % and a mean (SD) low error of 3.0 (2.0) %. The high error range was 0.1-8.0 %, with a mean (SD) high error of 4.2 (2.0) %. A one-way ANOVA test showed significant differences ($p < 0.001$) between actual flow delivered by different flowmeters at the same setting. **Conclusion**: Although we observed statistically significant differences between the flowmeters, we conclude that all are clinically acceptable for use. The high accuracy may be related to the low flow range and lack of service time. Because the price of these flowmeters ranges from $25 to $185, we recommend that flowmeter accuracy be tested at 1-year intervals of service to determine whether higher priced devices maintain acceptable accuracy longer than those available at lower cost. (OF-90-127)

An Evaluation of the Nonin 8800 Pulse-Oximeter Reflectance Probe—Joy E Hargett BS RRT, James Burchfield BS RRT, John S Sabo MS RRT, Wadie Williams RRT, Barbara Felder CPFT, Elizabeth F Bearden RRT, Steven Hageman CPFT RRT. St Luke's Episcopal Hospital, *Houston, Texas.*

We evaluated the accuracy of the reflectance probe (Part No. 8604R) of the Nonin 8800 Pulse Oximeter (Nonin Medical, Plymouth MN). This probe utilizes a single-sided sensor to analyze wavelengths of light. The reflectance and absorption sensors of the unit utilize common algorithms to determine oxygen saturation by pulse oximetry (S_{pO_2}). **Methods & Materials**: Two groups of subjects were included in this study: Group 1 consisted of 20 healthy volunteers, with informed written consent; Group 2 consisted of 20 adult postoperative cardiovascular patients. In both groups of subjects, S_{pO_2} determined by the Nonin 8800 was compared to arterial oxygen saturation (S_{aO_2}) measured by an IL 482 CO-Oximeter (Instrumentation Laboratory, Lexington MA). In Group 2, heart rate determined by the Nonin 8800 was compared to heart rate determined by the Siemens Sirecust 404-1 Cardiac Monitor (Siemens Life Support, Schaumburg IL). The reflectance probe was placed on each subject's forehead. After a baseline of 15 min, arterial samples were obtained while simultaneous readings were taken from the Nonin 8800. Arterial samples were drawn from the radial artery in Group 1 and from an indwelling arterial line in Group 2. **Results**: In Group 1, the mean (range) S_{aO_2} was 96.6 (93-98) %, and the mean (range) S_{pO_2} was 97.25 (94-98) %. In Group 2, the mean (range) S_{aO_2} was 97.25 (94-99) %, and the mean (range) S_{pO_2} was 98.7 (96-100) %. In Group 2, mean (range) pulse was 89.15 (54-123) beats/min as determined by the Nonin 8800, and 89.8 (54-130) beats/min as determined by the Siemens 404-1. A two-tailed paired *t* test revealed that S_{pO_2} determined by the Nonin 8800 was statistically higher than S_{aO_2} measured by the IL 482 ($t = 5.64$, $p < 0.0001$). (The correlation coefficient was 0.618.) A two-tailed paired *t* test revealed that heart rate determined by the Siemens 404-1 was higher than heart rate determined by the Nonin 8800 ($t = -1.53$, $p < 0.142$). (The correlation coefficient was 0.996.) **Conclusions**: Although differences were observed between Nonin 8800 S_{pO_2} and IL 482 S_{aO_2} values and between Nonin 8800 and Siemens 404-1 pulse values, it is unclear whether these differences are clinically important. We recommend further investigation of reflectance-probe technology. (OF-90-068)

Non-Bronchoscopic Diagnosis of *Pneumocystis carinii* Pneumonia: Is it Cost-Effective?—Michael S Benson BS RRT, Paul S Kubilis MS, Harborview Medical Center; David J Pierson MD, Harborview Medical Center and University of Washington—*Seattle, Washington.*

Sputum induction (SI) using nebulized hypertonic saline is potentially a less invasive, more economical alternative to bronchoscopy with bronchoalveolar lavage (BL) for diagnosing *Pneumocystis carinii* pneumonia (PCP); investigators at several institutions report positive SI in 55-95% of patients with proven PCP. However, the sensitivity of SI (SI_{sens} = patients positive by SI/patients with PCP) may vary in different patient populations with varying prevalence of PCP (PCP_{prev} = patients with PCP/patients referred for workup), and also in different clinical laboratories. At our institution, SI using the Brompton protocol (Lancet 1989;2:205) has recently become the usual intitial diagnostic procedure in suspected PCP, followed by BL if negative. To assess the cost-effectiveness of this approach, we attempted to determine SI_{sens} in all patients referred for PCP diagnosis in our institution from 10/89 through 5/90. We also assessed the personnel and monetary costs by prospectively determining the actual time spent by staff members on SI plus specimen handling for these cases, and determined the actual charges (hospital plus profesional-fee) for both SI and BL. Therapist time per SI attempt (measured interval from leaving to returning to department) averaged 43.8 minutes (range 15-120 minutes); the charge developed for SI (time + equipment) was $70.00. Total charges for attempted PCP diagnosis were $278.30 for SI ($SI_{cost}$) and $741.30 for BL ($BL_{cost}$). In 45 consecutive patients, 50 specimens were submitted to the laboratory from 56 SI attempts. Forty specimens contained stainable alveolar macrophages and were considered adequate for examination: 9 were positive for Pneumocystis, all on the first specimen submitted. Seventeen patients with negative SI subsequently underwent BL, and 7 had PCP; the other 19 patients either refused BL (3 patients), were treated presumptively for PCP (6 patients), or had other diagnoses made (10 patients). Whether SI is cost-effective in a given institution and patient population requires consideration of SI_{cost}, BL_{cost}, SI_{sens}, and PCP_{prev}. Because not all of our patients went on to definitive diagnosis, we cannot determine PCP_{prev} with certainty. SI_{sens} was thus somewhere between 41% (9/[16 + 6], assuming the 6 presumptively treated patients all actually had PCP) and 56% (9/16, or [+]SI/{[+]SI + [+]BL[, assuming none of the 6 had PCP). However, within this possible SI_{sens} range of 41-56%, given our institution's SI_{cost} and BL_{cost}, SI prior to BL is not cost-effective, and we are re-evaluating our institutional policy. SI could be made more cost-effective by better screening of patients referred for workup (increasing PCP_{prev}) or by improving SI_{sens}. In addition, the higher the cost of BL in relation to that of SI, the more cost-effective SI would be for a given SI_{sens} and PCP_{prev}. To facilitate this type of analysis, we have developed a simple graphic method for relating SI_{cost}, BL_{cost}, SI_{sens}, and PCP_{prev}, which can be used in any institution and for any patient population to determine whether SI is likely to be cost-effective in the evaluation of patients with suspected PCP. (OF-90-140)

Neonatal-Pediatric Lung Mechanics

Determination of Volume Accuracy at Different Compliances in Infant Pulmonary Function Equipment—Karen Turrentine BS RRT, Robert H Warren MD, Darrell Benham RRT. Arkansas Children's Hospital, *Little Rock, Arkansas.*

System accuracy of tidal volume (V_T) and compliance (C) was measured with three infant pulmonary function systems currently on the market. **Methods**: The Med-Science RDS-4500, Medical Associated Services PEDS, and the Infrasonics StarCalc were each tested under identical conditions. A Sechrist ventilator, delivering 100% oxygen and equipped with a circuit 60 cm in length, was set at IMV 30 breaths/min, PIP 20 cm H_2O, PEEP 2 cm H_2O, T_I 0.4 s, and flowrate 10 L/min. Pressures were measured with the Novametrix Pneumogard 1230A and Biotec Ventilator Tester Model VT-2. A compliance of 1 mL/cm H_2O was obtained directly from the VT-2. Specific compliances of 0.64 and 0.32 mL/cm H_2O were obtained using a system that incorporated glass bottles of 500-mL and 250-mL capacities into which a known volume (V) was inserted; pressure (P) was read by the VT-2. Compliance was calculated by dividing ΔV_T by ΔP ($C = \Delta V_T/\Delta P$). The glass capacitors were filled with copper wool to ensure isothermal conditions during compression. The capacitors and the VT-2 were connected in-line to a flow resistor of 200 cm $H_2O \cdot s \cdot L^{-1}$. With the Sechrist ventilator in operation, volume and compliance measurements were obtained from the infant pulmonary function systems five times each at the three compliance settings. The measured volume of each device was compared to a calculated volume derived by multiplying the compliance of the test lungs by the corresponding pressures generated within them ($V = CP$). **Results**:

Comparison of Known and Measured Volume (V) & Compliance (C)*

	Known		PEDS				StarCalc				Med-Science			
	V	C	V	%D	C	%D	V	%D	C	%D	V	%D	C	%D
Mean	18.00	1.00	19.28	7	1.10	10	16.98	6	1.10	10	17.07	5	0.95	5
SD			0.38		0.00		0.31		0.05		0.42		0.03	
Co Var			1.98		0.00		1.80		4.14		2.47		2.77	
Mean	11.52	0.64	11.03	4	0.61	5	9.74	15	0.54	15	12.07	5	0.67	5
SD			0.38		0.01		0.31		0.01		0.42		0.02	
Co Var			3.42		1.34		3.14		2.10		3.45		3.22	
Mean	5.76	0.32	6.23	8	0.36	13	5.01	13	0.28	13	4.86	16	0.27	16
SD			0.15		0.01		0.15		0.08		0.12		0.01	
Co Var			2.41		2.68		3.03		2.97		2.43		3.02	

*V is mL, C is mL/cm H_2O, and %D is %difference from known values.

Conclusions: The relative accuracy of volume and compliance measurements can be determined using a laboratory constructed lung model system. Infant pulmonary function systems should undergo periodic testing under laboratory conditions to monitor for deterioration of accuracy with time and use. (OF-90-061)

Pulmonary Mechanics during Mechanical Ventilation: Are There Optimum Settings To Collect Data?—Mary McGowan CRTT, Emidio Sivieri MS, Vinod K Bhutani MD. Pennsylvania Hospital, *Philadelphia, Pennsylvania.*

Pulmonary mechanics measured during mechanical ventilation differ from those measured during spontaneous breathing. In some cases, inadvertent distortion may occur due to high inflating pressure (PIP), excessive airflow ($\dot{V}$), or prolonged inspiratory time (T_I). To assess the individual effects of $\dot{V}$, PIP, rate (f), end-distending pressure (PEEP), and T_I during mechanical ventilation, five sick preterm infants with RDS were studied (mean [SD] birthweight 0.8 [0.08] kg, gestational age 27 [1.5] weeks, age 18 [9] days). **Methods**: All infants were being ventilated with the BEAR Cub ventilator (Bear Medical Systems Inc, Riverside CA). Tidal volume (V_T), dynamic compliance (C_{dyn}), and total resistance (R_{tot}) were measured at the original settings at which the infants were being ventilated; then measurements were made after each of the following ventilator-setting changes: ΔPIP to 13 cm H_2O, followed by a random ΔPEEP to 2 cm H_2O, ΔV to 8 L/min, Δf to 60 breaths/min, and ΔT_I to 0.3 s. Measurements were also made at settings commonly used for the measuring and reporting of pulmonary mechanics: original PIP settings, f 60 breaths/min, PEEP 2 cm H_2O, T_I 0.5 s, and $\dot{V}$ 8 L/min. **Results**:

Effects of Ventilator Changes on Pulmonary Mechanics in 5 Sample Infants*

	V_T	C_{dyn}	R_{tot}†
Orginal Settings	6.0 (1.6)	0.45 (0.21)	121 (45)
ΔPIP	5.0 (2.1)	0.46 (0.24)	119 (56)
ΔPEEP	5.7 (1.6)	0.40(0.13)	132 (52)
$\Delta\dot{V}$	6.0 (3.1)	0.41 (0.21)	128 (53)
ΔT_I	4.2 (0.9)	0.42 (0.22)	146 (57)
Commonly Used Settings	7.1 (2.2)	0.42 (0.14)	122 (50)

*All values are shown as mean (SD); V_T is in mL/kg, C_{dyn} is in mL/cm H_2O, R_{tot} is in cm $H_2O \cdot s \cdot L^{-1}$.

†R_{tot} is a measure of average resistance during the entire breath cycle.

Important changes in pulmonary mechanics were evident with a singular change in ventilator parameter. In evaluating the linear regression of the pressure-volume data for each study, reduction of PIP, $\dot{V}$, and T_I appear to provide optimum data that reflect the linear change similar to spontaneous breathing. **Conclusion**:These data suggest that $\dot{V}$, PIP, and T_I need to be standardized for data collection during mechanical ventilation to ensure appropriate day-to-day comparison of pulmonary mechanics. (OF-90-091)

Ventilator Circuit Flow Does Affect Lung Mechanics of Ventilated Infants—Wesley R Brown CRTT, Gerald Nystrom MD, Douglas Deming MD. Loma Linda University Medical Center, *Loma Linda, California.*

Infant ventilator circuit flows are not carefully controlled in the clinical setting. We sought to determine whether ventilator-circuit flow affects lung mechanics. **Methods**: In eight ventilator-dependent premature infants, we measured transpulmonary pressure, inspiratory and expiratory gas flow, and volume (electronic integration of flow) at three different ventilator-circuit flows: 4, 8, and 12 L/min. The Sechrist 4100B ventilator (Sechrist Industries Inc, Anaheim CA) was used in this study. Ventilator frequency and peak-inspiratory and end-expiratory pressures were held constant. Only ventilator breaths undisturbed by spontaneous respiration were evaluated. Inspiratory resistance (R_I), compliance, work (W_I), and

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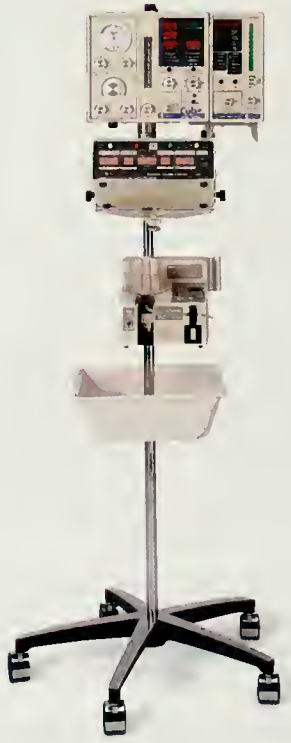

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volume were calculated by least mean squares technique. **Results:**

The Effect of Ventilator Circuit Flow on Inspiratory Lung Mechanics*

Ventilator Circuit Flow (L/min)	R_I (cm $H_2O \cdot s \cdot L^{-1}$)	W_I (g · cm · kg^{-1})
4	86 (19)	11 (3)
8	124 (32)	19 (4)
12	149 (24)	32 (4)

*All R_I and W_I values are shown as mean (SD).

Ventilator-circuit flow of 12 L/min resulted in significantly greater R_I and W_I than did flow of 4 L/min ($p < 0.01$, sign test) and in significantly greater W_I than did flow of 8 L/min ($p < 0.01$, one-way ANOVA). Ventilator-circuit flow of 4 L/min resulted in lowest R_I in six of the infants and lowest W_I in seven of the infants. Inspiratory compliance and volume were not significantly affected by ventilator-circuit flow. **Conclusions:** Our findings suggest that ventilator-circuit flow can significantly alter inspiratory lung mechanics and should be controlled when serial determinations of lung mechanics are performed. We speculate that increases in W_I are related to increases in R_I, which may be due to increased turbulent flow or changes in lung volume. (OF-90-145)

Clinical Effects of Bolus Fentanyl on Lung Compliance in Neonates and Infants—Noah D Perlman BS RRT, Jose Irazuzta MD, John E Thompson RRT. The Children's Hospital, *Boston, Massachusetts.*

The synthetic narcotic fentanyl is the most common analgesic employed in our multidisciplinary intensive care unit. When given in bolus doses (3 μ g/kg) to children, a decrease in lung and chest-wall compliance has been demonstrated. These effects are presumed to be secondary to an increase in muscle tone of the thoracic wall, leading to chest-wall rigidity. We studied dynamic compliance (C_{dyn}) to evaluate the clinical impact of this complication. **Methods:** We evaluated 13 intubated mechanically ventilated patients (< 4 mo of age) admitted to our intensive care units with various diagnoses. Each patient received a fentanyl bolus (4 μg/kg) prior to a painful procedure. All patients were on a volume-cycled ventilator with less than 20% endotracheal-tube-leak. Patients had not received any narcotics or neuromuscular blocking agents for 4 h prior to the study. C_{dyn} was measured continuously from 10 min prior to administration of the fentanyl until 10 min following infusion, using the StarCalc (Infrasonics Inc, San Diego CA) pulmonary function computer with the 30 L/min pneumotach. **Results:** 11 of the 13 patients showed improvement in C_{dyn}, and the remaining 2 patients showed no change in C_{dyn}. Mean (SD) specific C_{dyn} for the entire group of 13 patients was 0.76 (0.21) mL · cm H_2O^{-1} · kg^{-1} prior to fentanyl, and 0.82 (0.18) mL · cm H_2O^{-1} · kg^{-1} after fentanyl ($p < 0.03$, paired t test). **Conclusion:** In our study with neonates and young infants, fentanyl at doses of 4 μ g/kg bolus did not decrease C_{dyn} under clinical conditions. The improvement in C_{dyn}, seen in 11 patients, is probably due to improved ventilator synchrony and muscle relaxation—if a decrease in chest-wall compliance was present, it was more than offset by muscle relaxation and ventilator synchrony. (OF-90-099)

Breathing Patterns Measured by Respiratory Inductive Plethysmography in Normal and CF Children—Karen Turrentine BS RRT, Robert H Warren MD, Sheila Alderson BS RRT. Arkansas Children's Hospital, *Little Rock, Arkansas.*

In this study we sought to determine through the use of respiratory inductive plethysmography whether differences in breathing pattern exist between normal and cystic fibrosis (CF) children. Respiratory inductive plethysmography (RIP) can measure breathing pattern noninvasively by transmitting the ribcage (RC) and abdomen (AB) compartment changes associated with ventilation through oscillator circuitry. **Method:** An RIP device (Respicomp System, Noninvasive Monitoring Systems, Miami FL) was used to measure breathing pattern in 14 normal and 14 stable CF children; routine spirometry was also performed on each child. The subjects ranged in age from 5 to 13 years. The children were age- and sex-matched. **Results:** Significant differences ($p < 0.02$) in height, weight, FVC, FEV_1, PEF, $FEF_{50\%}$, and FEV_1/FVC were observed between groups. Breathing pattern data measured by RIP are listed as follows:

	Normal	CF	p Value
Frequency (breaths/min)	20.5 (3.1)*	27.8 (7.8)	0.003
Minute Volume (L)	5.56 (1.64)	6.02 (2.03)	NS
Inspiratory Time (s)	1.25 (0.21)	1.00 (0.28)	0.013
Expiratory Time (s)	1.81 (0.35)	1.36 (0.40)	0.004
Expiratory Flow (mL/s)	164.7 (57.9)	179.1 (66.3)	NS
Phase Angle†	16.1 (10.6)	9.1 (8.7)	NS
MCA/Tidal Volume†	1.02 (0.02)	1.02 (0.01)	NS

*All values are shown as mean (SD).

†Phase angle and maximum compartmental amplitude (MCA)/tidal volume are indicators of overall phasic relations between RC and AB motion.

Conclusions: With the exception of frequency and inspiratory and expiratory time, the results of this study suggest that the quietly awake breathing patterns of children with stable CF, as measured by RIP, are similar to those of normal children. No asynchrony or paradoxical motion between the RC and AB compartments was observed. (OF-90-021)

Using Flow-Volume Measurements To Assist in Extubation of an Apparent Ventilator-Dependent Child—John A Lund BA CRCP, Jon L Swegarden BS RRCP, Gerald F Atwood MD. Children's Hospital-MeritCare, St Luke's Hospitals, *Fargo, North Dakota.*

One of the many uses of bedside lung mechanics in infants and children is utilizing flow-volume (F-V) measurements to aid in diagnosis of large- and small-airways disease. **Case Summary:** A 5-mo-old 4.6-kg girl with no known underlying pulmonary disease underwent ventricular septal defect repair. Despite repeated attempts to wean her from mechanical ventilation, she remained ventilator dependent postoperatively for 10 days without clinical or radiologic evidence to support

the need. On Postoperative Day 11, we obtained F-V loops utilizing the SensorMedics 2600 Pediatric Pulmonary Function Testing System (SensorMedics, Yorba Linda CA). We determined from tidal expiratory flow patterns that she had large- and small-airways obstruction. Nebulized albuterol (1 mg) was then administered, and F-V loops were repeated 25 min later. The results indicate a dramatic improvement.

F-V Loop Data Pre- and Post-Bronchodilator

	Pre-Albuterol	Post-Albuterol	%Δ
V_T/kg (mL)*	5.1	7.0	37.30
%V/PTEF	0.08	0.38	375.00
TEF25/PTEF	0.35	0.77	120.00
PTEF (mL/s)	43.0	89.1	107.20
PTIF (mL/s)	52.2	116.3	122.80

*V_T = tidal volume, V = volume, PTEF = peak tidal expiratory flow, TEF_{25} = tidal expiratory flow at 25% of tidal volume, PTIF = peak tidal inspiratory flow.

The patient was subsequently started on theophylline elixir (16 mg) q 6 h and nebulized albuterol (1 mg) q 4 h. She was extubated 1 hour later on Postoperative Day 11. She remained extubated and was transferred from intensive care and later discharged. **Conclusions**: This case demonstrates that F-V loops and %V/PTEF measurements may be useful in the management of ventilator-dependent patients. We suggest that reactive airways disease be suspected and F-V measurements be made in post-operative ventilator-dependent children who fail to present clinical evidence supporting the need for mechanical ventilation. (OF-90-107)

Staffing and Continuing Education

Tidal Volume, Minute Ventilation and Respiratory Rate Delivered to a Mannequin by Paramedic Students and Respiratory Care Students using Pocket Mask versus Demand Valve—Robert R Fluck Jr MS RRT, Joseph G Sorbello MS RRT. SUNY Health Science Center, *Syracuse, New York.*

The purpose of this study was to determine whether differences are present in respiratory rate (f), tidal volume (V_T), and minute ventilation ($\dot{V}_E$) produced by paramedic students and second-year respiratory care (RC) students ventilating a mannequin using three different methods: pocket mask (Method I), demand valve with one hand (Method II), and demand valve with two hands (Method III). **Method & Materials**: 15 students enrolled in a paramedic course at our institution (EMT-4) (all of whom were basic emergency medical technicians with various amounts of field experience) and 16 second-year RC students were the subjects of our study. The subjects ventilated a mannequin for 5 minutes by each method, with a 10-min rest between methods. (The method sequence was randomly chosen for each subject.) The same mannequin (Laerdal Medical Corp, Armonk NY), pocket mask (Laerdal Medical Corp), and demand valve (Robertshaw Controls, Anaheim CA) were used by all subjects for all trials throughout the study; however, each subject received his own one-way valve for pocket mask trials. Ventilation was measured during the first and last minutes of each trial by a VM-90 spirometer (Bear Medical Sytems, Riverside CA) attached to the exhalation port of the mannequin. (The VM-90 was checked with a 1-L calibration syringe to ensure that it performed within the manufacturer's stated accuracy of ±5%.) The subject was unable to see either the volume-indicating device on the mannequin or the VM-90 display; however, a clock with a sweep second hand was in plain view at all times. Statistical analysis of the data was done using the two-factor repeated measures of analysis of variance (ANOVA); we considered statistical significance to be $p < 0.05$. **Results**: The RC students' f was much higher for all three methods compared to EMT-4 students' f. The EMT-4 students demonstrated larger V_T for each method compared to the RC students. The RC students only achieved acceptable V_T with Method III. Both EMT-4 and RC students demonstrated statistically significant differences in $\dot{V}_E$ between each method. However, the clinical importance of these differences for EMT-4 students seems to be negligible. While the EMT-4 students as a group achieved minimally acceptable mean V_T with the pocket mask—40% were unable to do so at 1 min, and 60% were unable to do so at 5 minutes. A great difference was seen in $\dot{V}_E$ produced by RC students with Method I (at both 1 and 5 minutes) vs Methods II and III. **Conclusions**: Our findings suggest that EMT-4 students may have superior ventilation skills compared to RC students. Superior performance skills may be related to: (1) different instructional methodologies and (2) the effects of various amounts of experience in ventilating actual victims. We are going to re-evaluate the methods that we use in the teaching, practice, and remediation of these basic but important clinical skills; we encourage other programs to do the same. Our findings are in agreement with a previous study that indicated the inability of rescuers to deliver adequate tidal volumes with the Laerdal pocket mask (Respir Care 1985;14:403-406). We recommend that area EMS providers and hospitals consider changing to an acceptable alternate mask in light of these and previous findings. (OF-90-060)

Nasal CPAP as a Respiratory Care Procedure—Brian L Smith RRT, University Hospitals of Cleveland; Michael J Decker CRTT, Case Western Reserve University; Frank J Caruso RRT, Barbara Braun RRT, University Hospitals of Cleveland; E Chandler Deal MD, Kingman P Strohl MD, Case Western Reserve University and University Hospitals of Cleveland—*Cleveland, Ohio.*

We developed a protocol for the Respiratory Care department to implement nasal continuous positive airway pressure (nasal CPAP) therapy. Eleven male medical inpatients, with clinical and objective evidence of moderately severe to severe obstructive sleep apnea, were offered nasal CPAP as a therapeutic option. In their rooms, during an afternoon session, the patients were fitted with and instructed in the use of the Respironics nasal CPAP mask (Respironics, Monroeville PA) and Healthdyne pump (Healthdyne Technologies, Marietta GA). Mask pressure was measured by water manometer, and oxygen saturation (S_{pO_2}) was monitored by Nellcor pulse oximeter with

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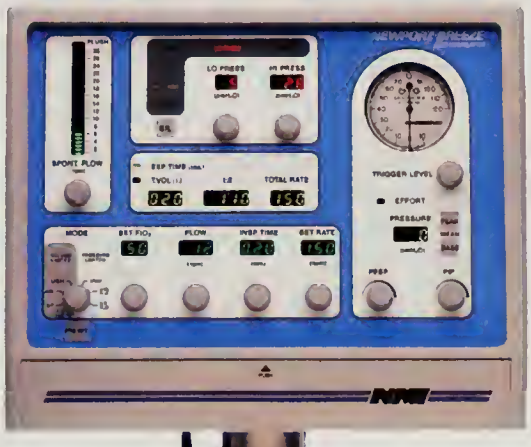

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strip-chart recorder (Nellcor Inc, Hayward CA). With the mask and tubing strapped in place, each patient was asked to fall asleep under the observation of a respiratory care practitioner (RCP). Once behavioral sleep was observed and repetitive desaturations were documented by oximetry, the CPAP pump (Healthdyne) was connected to the tubing and pressure was incrementally raised until snoring and episodic desaturations were eliminated. To document the effect of nasal CPAP, the pressure required to eliminate snoring and desaturations (7.5-18 cm H_2O) was abruptly discontinued to demonstrate that without positive pressure the patient returned to a pattern of cyclic desaturations. These desaturations were alleviated when positive pressure was restored. This approach was successful initially in 9 of the 11 patients (two were unable to sleep) and was successful the following day in the remaining two. That night each patient set up and administered his own nasal CPAP therapy under the observation of an RCP, and S_{pO_2} was again monitored to identify any sleep-associated desaturations not evident during the afternoon trial. During routine rounds, the RCP could correct any desaturations by increasing mask pressure. The patients were discharged the following day to be followed up in 1 wk by the physician and an RCP. **Conclusion**:We conclude that application and documentation of effective levels of nasal CPAP for treatment of moderately severe to severe sleep apnea syndrome can be implemented by RCPs. (OF-90-033)

An Evaluation of a Systematic Approach to Budget for Educational Programs—Sandra Ollivier RRT, John S Sabo MS RRT, Cynthia E Mehling BS RRT, Joy E Hargett BS RRT. St Luke's Episcopal Hospital, *Houston, Texas.*

An analysis of educational program planning associated with a 24-month managerial strategy was performed. A variety of operational changes included obtaining new equipment, expanding services, and making major modifications to existing procedures. **Method**: A systematic approach was developed to complete educational programs associated with these changes. Important aspects were time lines, target dates, and clear program objectives. Common components of each program included: (1) preparing literature packets and lecture outlines, (2) planning the schedule to ensure minimal patient-care disruption, (3) training, and (4) conducting performance evaluations (written and practical). The goals of using this approach of preplanning for each program were: to complete training within budgeted educational hours, to minimize the need for retraining, and to implement each program by the specified target date. Accomplishing these goals would ensure successful program implementation. **Results**: Analysis of 18 programs for 85 full-time equivalents in which 97 employees were trained revealed: (1) 16 of 18 (88%) programs were completed prior to the specified target date. (2) Whereas 1,584 educational hours had been budgeted, 1,674 h were actually used (ie, a variance of 5.66%). Actual average training time per program was 2.02 h (range, 1-13.5 h). (3) Of 830 episodes of training, 23 incidents of failure to meet minimal standards and retraining occurred, or 2.77%. (4) Of the total programs, 17 (94%) were successfully implemented. One program was suspended because of operational issues. Actual average preparation time per program was 19.14 hours (range, 4.25 - 38.5 h). **Conclusion**: There is a cost investment of time required for technologic change. Our approach allowed us to budget time for training by identifying the number of hours required for each component of the educational processs. We continue to use this approach for educational projects. (OF-90-013)

Development and Implementation of a Critical Care Course for Respiratory Care Services in a Pediatric Hospital—Sherry L Barnhart RRT, Darrell Benham RRT. Arkansas Children's Hospital, *Little Rock, Arkansas.*

After observing that many practitioners in our department did not feel competent in caring for a critically ill child, we developed a pediatric critical care course. Input from pulmonologists, RCP staff members, and the critical care units' medical directors was solicited to determine job-related needs, frequency of procedures performed in the units, and preferred course topics. Course content was designed to focus on patient assessment, lab tests, disease reviews, case studies, departmental policies and procedures, charting, and health-team-member leadership skills. The course was 80 hours in length, limited to 4 persons/class, and utilized lecture, discussion, demonstration, video/audio tapes, self-instructional programs, and laboratory sessions. **Method**: Successful completion of written pre- and post-course tests and clinical proficiency exams allowed participants to work in the critical care units. Course effectiveness was evaluated by assessing: improvement in written test scores (post- vs pre-course), post-course questionnaires addressing the attitude of participants towards the course, and supervisors' evaluation of participants' post-course performance. **Results**: Sixty participants completed the course. The mean (range) pre-course test score was 50 (20-88), and mean post-course score was 82 (64-96). The questionnaires indicated that the participants felt more confident in working with critical care patients and other health team members; more informed about policies and procedures; and positive towards course content but overwhelmed by its scope and depth. Supervisors reported that after the course the participants were more willing to interact with medical staff, were better able to solve problems, required less supervision in direct patient care, and were viewed more positively by other health care team members. The course has proven to be cost-effective; not only has it been useful as a recruitment tool, but it has resulted in a decline in staff turnover, a decrease in the number of departmental incident/accident reports, and a decreased need for supervisors to spend time counseling employees. Other perceived benefits include a renewed sense of staff interest in work, meeting staff learning needs, standardization of care, development of clinical proficiency exams, and an avenue is now in place for continued improvement in the quality of patient care. The course has been incorporated into our department's New Employee Orientation Program. (OF-90-027)

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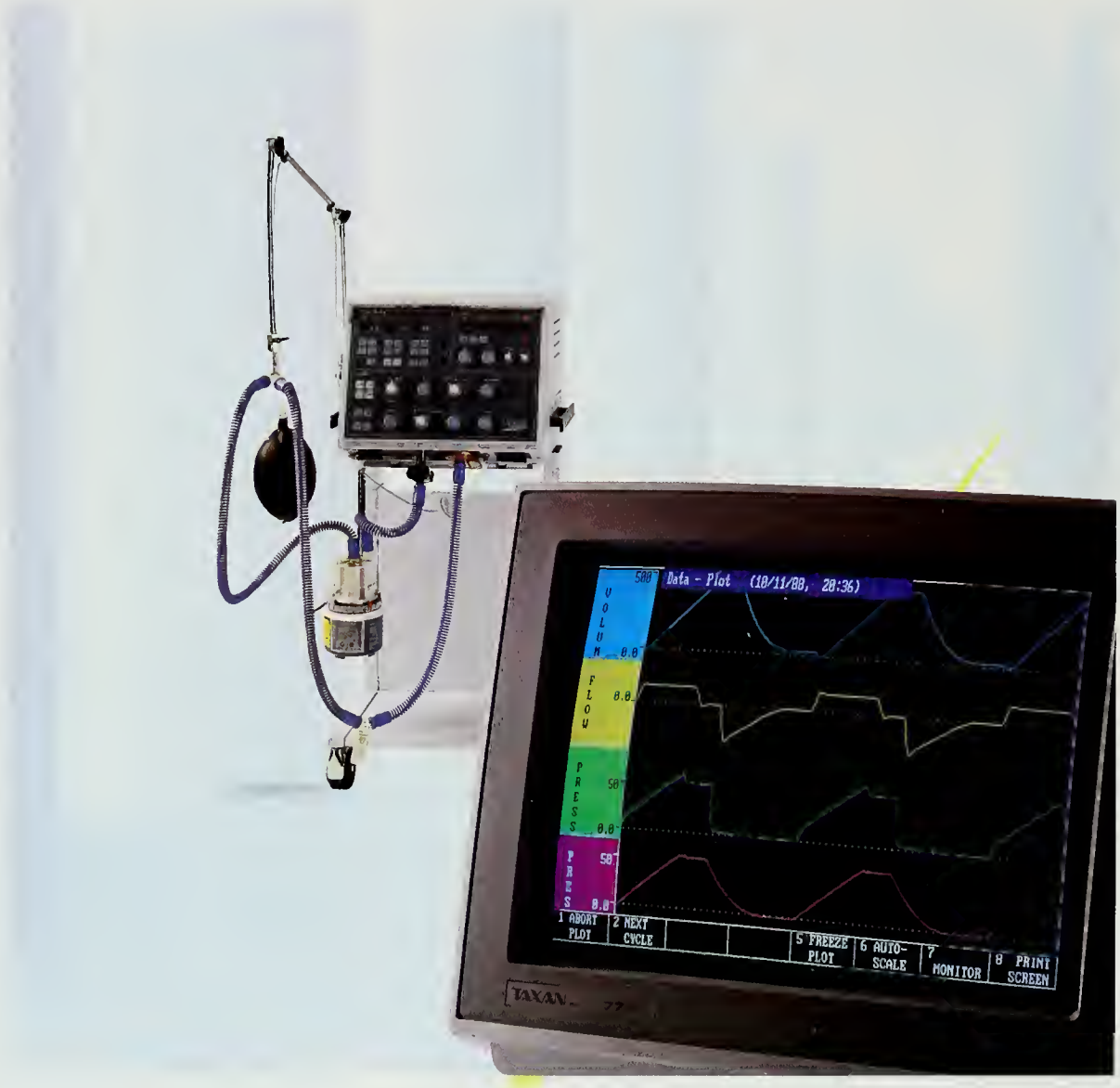

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Occupational Stress and Overall Coping Resources for Stress—Donald F May PhD RRT RPFT, Harmon Fowler EdD. Georgia State University, *Atlanta, Georgia.*

In this study we sought to answer the questions Is there a relationship (1) between any professional characteristic of respiratory care practitioners (RCPs) and the level of occupational stress (OS) experienced? and (2) between hospital organizational variables and OS experienced by RCPs? (3) between level of OS and levels of overall coping resources effectiveness for stress (OCRES) in RCPs? **Methods**: 98 RCPs from 5 metropolitan hospitals completed self-report scales measuring OS, CCRES, and professional characteristics (37% response rate). Subjects included RRTs (65), CRTTs (25), and OJT-RCPs (8); average years in the field was 9.5. Types of hospitals studied included 2 public community hospitals, 2 private community hospitals, and 1 private for-profit hospital. Patient beds ranged from 293-933. OCRES is a composite value derived from measured levels of 12 common coping mechanisms for stress and is indicative of an individual's general stress-coping ability; OCRES values range from 0-100. OS reflects the attitude of the subject toward health-care work; values for OS range from 18-72. The Coping Resources Inventory for Stress (Matheny et al, 1987) was used to measure OCRES, and the Health Professionals Stress Inventory (HPSI) (Revicki and May, 1983) to measure OS. Internal reliability (Cronbach's alpha) for OCRES has been determined in previous research as 0.97. Significant and strong correlations in expected direction have been measured between OCRES and other variables related to stress. Cronbach's alpha for HPSI has been reported in previous research as 0.89. Significant correlations for HPSI and other measures of occupational stress have been determined. **Results**: No differences in OS or OCRES in the sample were determined based upon gender or age of subjects. Level of OS in the sample was found to be significantly related to the level of OCRES ($r = -0.45$, $p = 0.0004$). Level of OS did not vary significantly with any of 6 characteristics of the hospitals, including type, size, number of employees, and credentials of the RCPs. None of the 8 individual professional characteristics measured (such as highest credential held, level of education completed, length of time in field, or shift worked) were determined to be significantly related to either OS or OCRES. The average number of hours worked/pay period was found to be significantly related to OCRES ($r = 0.19$, $p = 0.05$) but not to OS. The level of OS in subjects with high OCRES (75th percentile) was determined to be significantly different from the level of OS in subjects with low OCRES (25th percentile), $p = 0.003$. No differences based upon individual professional characteristics could be identified between high OCRES and low OCRES subjects. **Conclusions**: Level of OS in this sample of subjects was significantly and negatively related to measured levels of OCRES. Subjects with high OCRES indicated significantly lower levels of OS than subjects with low OCRES. However, the level of OS in the sample was not found to vary significantly with any of the individual professional characteristics or selected organizational characteristics of the hospitals. Therefore, OS in this sample of RCPs may be a function of personal attributes unrelated to either professional or organizational characteristics of the hospital at which the RCP is employed. (OF-90-024)

Burnout, Job Satisfaction, and Attrition in Respiratory Care—David C Shelledy PhD RRT. Georgia State University, *Atlanta, Georgia.*

The purpose of this study was to determine the organizational, job-specific, and individual predictors of burnout among respiratory care practitioners (RCPs) and to examine the relationships between job satisfaction, absenteeism, employee attrition, and burnout. **Method**: An assessment instrument was constructed for collection of the data of interest and was pilot-tested and distributed to all active NBRC-credentialed RCPs in a large southeastern state ($n = 788$). A random sample consisting of 10% of the nonrespondents ($n = 33$) was then surveyed by telephone and compared to the respondents. Variables were compared to burnout scores using the Pearson product moment correlation. This was followed by multiple regression analyses to determine the ability of the significant variables to predict burnout scores when used in combination. **Results**: 465 usable returns (response rate 59%). No significant differences in burnout or job satisfaction ($p = 0.56$ and 0.24, respectively) between respondents and nonrespondents; 24 significant ($p < 0.05$) correlations between specific organizational and job-related factors and burnout; 8 significant ($p < 0.05$) correlations between demographic, professional, and personal characteristics of the individual and burnout. When used in combination, these factors accounted for 57% of the variance observed ($r = 0.75$; $p < 0.0001$). As job satisfaction increased, there was a significant decrease in burnout ($r = -0.59$; $p < 0.001$). As burnout increased, there was a significant increase in absenteeism due to illness ($r = 0.23$; $p = < 0.001$), absenteeism due to other problems ($r = 0.10$; $p = 0.029$), and total absenteeism ($r = 0.22$; $p < 0.001$). Finally, as burnout increased, there was a significant increase in attrition as intent to leave the job ($r = 0.48$; $p < 0.001$) and attrition as intent to leave the field ($r = 0.51$; $p < 0.001$). **Conclusions**: Of the organizational and job-related variables, the strongest predictors of burnout based on regression analysis were difficulty in obtaining time off, lack of job control, decreased recognition by nursing, lack of role clarity, increased job stress, and decreased satisfaction with work. Of the individual variables, the strongest predictors of burnout were decreased age, increased number of dependent children, lack of social support, and poor health. There was also a significant negative relationship between job satisfaction and burnout, a significant but weak positive relationship between burnout and absenteeism, and a positive relationship between burnout and attrition. Minimizing those factors associated with burnout among RCPs may improve job performance and the quality of patient care and reduce both absenteeism and attrition. (OF-90-003)

Are Entry-Level Salaries in Respiratory Therapy Keeping Pace with the Annual Rate of Inflation?—David W Chang MEd RRT. Columbus College, *Columbus, Georgia.*

I sought to determine whether entry-level salaries of respiratory therapists and technicians keep pace with annual rates of inflation. **Method:** I used the results of national surveys conducted by the Committee on Allied Health Education and Accreditation (American Medical Association, Allied Health Education Fact Sheets [1982-1987], and Allied Health Education Directories [1988-1990]) to compile the entry-level salary data of respiratory therapists and respiratory therapy technicians from 1981 to 1989. Over a 9-year period, an average of 410 respiratory therapy programs were surveyed per year; the average survey return rates were 92% for the therapist programs and 84% for the technician programs. I used the 1981 entry-level salaries as the base salaries and calculated the inflation-adjusted salaries for 1982 through 1989 by multiplying the salary of the previous year by the prospective annual inflation rate (Bureau of Labor Statistics, U.S. Labor Department). The entry-level salaries were compared to the inflation-adjusted salaries for statistical differences. **Results:** The annual entry-level salaries for 1981 through 1989 were: $15,650; $16,037; $16,424; $16,812; $17,724; $18,636; $19,290; $20,527; $21,907 for therapists and $12,670; $13,234; $13,798; $14,362; $14,923; $15,484; $16,044; $16,807; $18,268 for technicians. The annual inflation rates from 1981 to 1988 were 10.4%, 6.1%, 3.2%, 4.3%, 3.6%, 1.9%, 3.6%, and 4.1%, respectively. The inflation-adjusted salaries for 1982 through 1989 were $17,278; $18,332; $18,918; $19,732; $20,442; $20,830; $21,580; $22,465 for therapists and $13,988; $14,841; $15,316; $15,974; $16,549; $16,864; $17,471; and $18,187 for technicians. When the entry-level salaries for respiratory therapists and respiratory therapy technicians were compared to the respective inflation-adjusted salaries, no statistical differences were found ($t = 1.601$ for therapists and $t = 1.023$ for technicians). **Conclusion:** From 1981 to 1989, the annual entry-level salaries of respiratory therapists and respiratory therapy technicians kept pace with the annual rates of inflation. (OF-90-111)

Comparing Retention of Proper Metered-Dose-Inhaler Self-Adminstration Technique in Patients Professionally-Instructed vs Self-Instructed—Patty Silver MEd RRT, M Darnetta Baker MBA RRT. The Jewish Hospital of St Louis at Washington University Medical Center, *St Louis, Missouri.*

The effectiveness of aerosolized medication delivery by metered-dose inhaler (MDI) is dependent upon the use of proper self-administration technique. We compared retention of proper MDI technique in 3 groups of hospitalized patients. **Methods:** Over a 3-year period at our hospital, the Respiratory Care Services (RCS) staff instructed 495 patients in a 9-step self-administration technique to be used with MDIs: Step 1—shake, Step 2—exhale, Step 3—hold upright, Step 4—position, Step 5—compress, Step 6—inspire, Step 7—hold breath, Step 8—wait 2 minutes, Step 9—state dose. To reinforce proper MDI self-administration, following instruction each patient was given a handout of the 9-step technique. Patients were categorized into 3 groups on the basis of MDI instruction received prior to being taught the 9-step technique by the RCS staff: patients previously instructed by RCS staff (RCSI) (n = 254), patients previously instructed by their physician (PI) (n = 74), and patients self-instructed (SI) (n = 167). There was no significant difference among the groups when comparing mean age, diagnoses, and sex. MDI self-adminstration performance was evaluated in each patient at 3 intervals: prior to RCS 9-step instruction, immediately following RCS 9-step instruction, and 48-to-72 hours after RCS 9-step instruction. **Results:** The percentages of patients performing at least 7 of the 9 steps correctly prior to instruction were: RCSI 71%, PI 73%, and SI 67%; immediately following instruction: RCSI 88%, PI 92%, and SI 83%; and 48-to-72 hours after instuction: RCSI 87%, PI 91%, and SI 82%. The percentage of patients correctly performing the 5 most critical steps (Steps 4-8) increased for all groups following initial instruction; however, the SI group continued to improve at the 48-to-72-hour interval. **Conclusion:**Our findings suggest that providing additional instruction to patients after initial MDI prescription (eg, during subsequent hospital visits) will lead to increased patient retention of proper MDI self-administration technique. (OF-90-129)

Selected Topics—Adult Acute Care

Newly Patented Disposable Self-Inflating Manual Resuscitator Bag—Lee Sitnik BA RRT. Lexington Medical Center, *West Columbia, South Carolina.*

A newly patented (Patent No. 4,870,962) disposable self-inflating manual resuscitator has been designed by the author of this abstract. (A working prototype of the resuscitator has not yet been made.) The resuscitator is to be manually actuated, self-distending, and self-inflating. It is to be shaped like a pleated, handleless bellows (see figure). In theory, following compression the pleats will act like a spring to rapidly and completely reinflate the bag. The flat sides of the bellows will enable the operator to easily compress the resuscitator with one hand or a knee, and there will not be a tendency for the resuscitator to roll away from the operator during the compression cycle. The resuscitator is to have at least one air and/or oxygen intake valve and one air exhaust port. In theory, as the resuscitator is compressed (and the walls collapse) a linear quantity of air will be expelled from the inner chamber of the bellows; this should make it much easier (than if he/she were using a spherical or football shaped resuscitator) for the operator to estimate how much air has been forced into the recipient's lungs. The resuscitator is designed so that one edge can be hinged, which will allow for a mechanical advantage feature to be incorporated into the design. The mechanical advantage feature is intended to enable the operator to perform one-handed ventilation (even in the presence of high airway pressure) without becoming physically fatigued, or to compress the resuscitator under an armpit or a knee so that both hands will be free to perform other tasks. Integrated single-piece construction is to be used for fabrication and pleats are to be constructed sufficiently thick to enable the bellows to fully recov-

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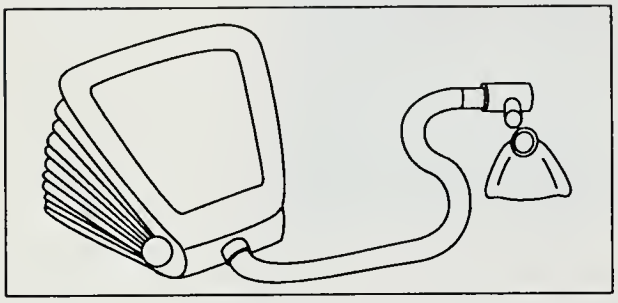
er within 4 seconds of complete compression. It is also intended that through the use of flexible tubing it will be possible to connect the resuscitator to a two-way inhalation-exhalation valve; the connecting tubing will theoretically enable the operator to move the resuscitator away from the airway or patient's face and to gain an unobstructed view of the patient.



(OF-90-022)

Evaluation of Five Permanent and Five Disposable Manual Adult Resuscitators at 0 °F—Thomas A Barnes EdD RRT, Northeastern University; Deborah L Stockwell, Beth Israel Hospital—*Boston, Massachusetts.*

We evaluated at 0 °F the minimum performance of 5 permanent manual adult resuscitators: Hope 4 (Matrx Medical), Laerdal Silicone (Laerdal Medical), Lifesaver (Hudson RCI), Mark 3 (Ambu), PMR (Puritan-Bennett); and 5 disposable manual adult resuscitators: BagEasy (Respironics), Code Blue (Vital Signs), CPR Bag (Mercury Medical), DMR (Puritan-Bennett), and Spur (Ambu). **Method**: We used the standards and methods approved by the American Society for Testing and Materials (F 920-85, ASTM Committee on Standards, Philadelphia, 1985:1-22) and the International Organization for Standardization (ISO 8382:1988 [E] prepared by the Technical Committee ISO/TC 121, Anaesthetic and Respiratory Equipment, ISO, New York, 1988:1-23). Ambient temperature was held at 0 ± 1 °F and relative humidity at 53 ± 3% by conducting the study in a climatic chamber. The resuscitators were in the chamber for a minimum of 4 hours at 0 °F before being evaluated. A Bio-Tek VT-1 Ventilator Tester was used as a lung model (C = 0.02 L/cm H_2O [0.20 L/kPa] and r = 20 cm $H_2O \cdot s \cdot L^{-1}$ [2 kPa · s · L^{-1}]). **Results**: The Spur was the only resuscitator to fail the ASTM and ISO requirements for V_T (600 mL), f (20/min), and I:E (< 1:1). The ASTM and ISO standards specify an $F_{DO_2} > 0.85$ (with O_2 reservoir) at O_2 flow of 15 L/min and $\dot{V}_E$ of 7.2 L/min (V_T 600 mL, f 12/min). Only the Code Blue (1.00 [0.01], mean [SD]), PMR (0.93 [0.01]), and DMR (0.89 [0.01]) met the F_{DO_2} requirement. The other 7 resuscitators had an $F_{DO_2} < 0.85$: Mark 3 (0.83 [0.06]), Lifesaver (0.81 [0.01]), Laerdal (0.73 [0.03]), BagEasy (0.66 [0.02]), Hope 4 (0.54 [0.02]), CPR Bag (0.53 [0.01]); the Spur was unable to deliver more than one V_T before collapsing. All resuscitators were functional at O_2 flow of 30 L/min except the Spur. Only the CPR bag failed the drop test (patient connector separated from patient valve); however, the oxygen reservoir of the Hope 4 shattered into small pieces when dropped from a height of 1 m, and the PEEP valve stem on the BagEasy snapped when dropped. The patient valve of all 10 resuscitators, when first placed in the chamber, remained functional to ventilate a subject for 10 min with exhaled gas passing through the patient valve. The patient valves of the resuscitators, when wet with exhaled water vapor, were still functional after being set aside for 5 min, except the Spur whose compressible unit collapsed. After 30 min of being set aside wet, the patient valves of the DMR and Lifesaver were partially frozen from ice formation and V_T delivery was limited to 200 mL and 600 mL, respectively. **Conclusion**: On the basis of our study, we conclude that the Code Blue, PMR, and DMR resuscitators are acceptable for use in the extremely cold temperature conditions of 0 °F. (OF-90-124)

Evaluation of Five Permanent and Five Disposable Manual Adult Resuscitators—Thomas A Barnes EdD RRT, Northeastern University; Deborah L Stockwell, Beth Israel Hospital—*Boston, Massachusetts.*

We evaluated minimum performance and safety of 5 permanent manual adult resuscitators: Hope 4 (Matrx Medical), Laerdal Silicone (Laerdal Medical), Lifesaver (Hudson RCI), Mark 3 (Ambu), PMR (Puritan-Bennett); and 5 disposable manual adult resuscitators: BagEasy (Respironics), Code Blue (Vital Signs), CPR Bag (Mercury Medical), DMR (Puritan-Bennett), and Spur (Ambu). **Method**: For evaluation of the resuscitators we used the standards and methods approved by the American Society for Testing and Materials (F 920-85, ASTM Committee on Standards, Philadelphia, 1985:1-22) and the International Organization for Standardization (ISO 8382:1988 [E] prepared by the Technical Committee ISO/TC 121, Anaesthetic and Respiratory Equipment, ISO, New York, 1988:1-23). A Bio-Tek VT-1 Ventilator Tester was used as a lung model (C = 0.02 L/cm H_2O [0.20 L/kPa] and r = 20 cm $H_2O \cdot s \cdot L^{-1}$ [2 kPa · s · L^{-1}]). **Results**: All of the resuscitators met the ASTM and ISO standards for V_T (600 mL), f (20/min), and I:E (< 1:1). All the resuscitators were able to deliver the American Heart Association (AHA) recommended V_T (800 mL), f (12/min), and I:E (< 1:2); however, a two-hand compression of the bags was necessary. The ASTM and ISO standards specify an F_{DO_2} of ≥ 0.85 with O_2 reservoir and ≥ 0.40 without O_2 reservoir at O_2 flow of 15 L/min and $\dot{V}_E$ of 7.2 L/min (V_T 600 mL, f 12/min). With O_2 reservoir, the Hope 4's mean (SD) F_{DO_2} was 0.77 (0.03), which was significantly lower ($p < 0.001$) than that of the other 9 resuscitators (≥ 0.93). Without an O_2 reservoir, the PMR's mean F_{DO_2} was 0.35 (0.01), which was significantly lower ($p < 0.001$) than that of the other 5 resuscitators with detachable reservoirs (≥ 0.40). At the ventilation pattern recommended by the AHA (800 mL x 12/min), the PMR's mean F_{DO_2} dropped to 0.86 (0.03) because air leaked into the bag where it attaches to the patient valve assembly. When disabled with simulated vomitus, all resuscitators were able to be restored to proper function within 20 seconds and were functional at O_2 flow of 30 L/min. All the resuscitators passed the backward leakage and drop tests required by ASTM and the 10-second immersion-in-water test required by ISO. **Conclusions**: On the basis of our study, we conclude that all the resus-

"I never thought we could be hit...
I mean, I knew it was possible,
but what were the chances?"

RSV.
No one knows the path it will take.

The consequences may have a lasting effect. The short-term consequences of respiratory syncytial virus (RSV) infection can include nosocomial spread, mechanical ventilation, extended hospitalization—even death—and can threaten *all* hospitalized children under 4 years old. Respiratory viral infections may have a long-term effect on the respiratory tree in some patients, such as development of bronchopulmonary disease.[1]

Help reduce the toll taken by RSV. In clinical experience with over 50,000 patients, treatment of appropriate patients with Virazole® (ribavirin) Aerosol improved disease symptoms safely, speeding recovery[2-6] while significantly reducing viral shedding.[2,4] Virazole may reduce the need for supplemental oxygen and mechanical ventilation.[7] And Virazole has been shown to prevent development of RSV-specific IgE responses,[8] which may correlate with the release of histamine and clinical expression of obstructive reactive airway disease.[1]

Serious enough to hospitalize, serious enough to consider

Virazole®
(ribavirin)
Lyophilized for aerosol administration

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Please see following page for full prescribing information.

SPI-132

Serious enough to hospitalize, serious enough to consider

Virazole®
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PRESCRIBING INFORMATION

WARNING: RIBAVIRIN AEROSOL SHOULD NOT BE USED FOR INFANTS REQUIRING ASSISTED VENTILATION BECAUSE PRECIPITATION OF THE DRUG IN THE RESPIRATORY EQUIPMENT MAY INTERFERE WITH SAFE AND EFFECTIVE VENTILATION OF THE PATIENT. Conditions for safe use with a ventilator are still in development.

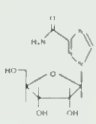
Deterioration of respiratory function has been associated with ribavirin use in infants, and in adults with chronic obstructive lung disease or asthma. Respiratory function should be carefully monitored during treatment. If initiation of ribavirin aerosol treatment appears to produce sudden deterioration of respiratory function, treatment should be stopped and re-instituted only with extreme caution and continuous monitoring.

Although ribavirin is not indicated in adults, the physician should be aware that it is teratogenic in animals (see CONTRAINDICATIONS).

DESCRIPTION:

Virazole® (ribavirin) Aerosol, an antiviral drug, is a sterile lyophilized powder to be reconstituted for aerosol administration. Each 100 ml glass vial contains 6 grams of ribavirin, and when reconstituted to the recommended volume of 300 ml with sterile water for injection or sterile water for inhalation (no preservatives added), will contain 20 mg/ml ribavirin, pH approximately 5.5. Aerosolization is to be carried out in a SPAG-2 nebulizer only.

Ribavirin is 1-beta-D-ribofuranosyl-1,2,4-triazole-3-carboxamide, with the following structural formula:



Ribavirin, a synthetic nucleoside, is a stable, white, crystalline compound with a maximum solubility in water of 142 mg/ml at 25°C and with only a slight solubility in ethanol. The empirical formula is $C_8H_{12}N_4O_5$ and the molecular weight is 244.2 Daltons.

CLINICAL PHARMACOLOGY:

Antiviral effects:

Ribavirin has antiviral inhibitory activity *in vitro* against respiratory syncytial virus,[1] influenza virus, and herpes simplex virus. Ribavirin is also active against respiratory syncytial virus (RSV) in experimentally infected cotton rats.[2]

In cell cultures, the inhibitory activity of ribavirin for RSV is selective. The mechanism of action is unknown. Reversal of the *in vitro* antiviral activity by guanosine or xanthosine suggests ribavirin may act as an analogue of these cellular metabolites.

Immunologic effects:

Neutralizing antibody responses to RSV were decreased in ribavirin treated compared to placebo treated infants.[3] The clinical significance of this observation is unknown. In rats, ribavirin resulted in lymphoid atrophy of thymus, spleen, and lymph nodes. Humoral immunity was reduced in guinea pigs and ferrets. Cellular immunity was also mildly depressed in animal studies.

Microbiology:

Several clinical isolates of RSV were evaluated for ribavirin susceptibility by plaque reduction in tissue culture. Plaques were reduced 85-98% by 16 μg/ml, however, plaque reduction varies with the test system. The clinical significance of these data is unknown.

Pharmacokinetics:

Assay for ribavirin in human materials is by a radioimmunoassay which detects ribavirin and at least one metabolite.

Ribavirin administrered by aerosol is absorbed systemically. Four pediatric patients inhaling ribavirin aerosol administered by face mask for 2.5 hours each day for 3 days had plasma concentrations ranging from 0.44 to 1.55 μM, with a mean concentration of 0.76 μM. The plasma half-life was reported to be 9.5 hours. Three pediatric patients inhaling ribavirin aerosol administered by face mask or mist tent for 20 hours each day for 5 days had plasma concentrations ranging from 1.5 to 14.3 μM with a mean concentration of 6.8 μM.

It is likely that the concentration of ribavirin in respiratory tract secretions is much higher than plasma concentrations in view of the route of administration.

The bioavailability of ribavirin aerosol is unknown and may depend on the mode of aerosol delivery. After aerosol treatment, peak plasma concentrations are less than the concentration that reduced RSV plaque formation in tissue culture by 85 to 98%. After aerosol treatment, respiratory tract secretions are likely to contain ribavirin in concentrations many fold higher than those required to reduce plaque formation. However, RSV is an intracellular virus and serum concentrations may better reflect intracellular concentrations in the respiratory tract than respiratory secretion concentrations.

In man, rats, and rhesus monkeys, accumulation of ribavirin and/or metabolites in the red blood cells has been noted, plateauing in red cells in man in about 4 days and gradually declining with an apparent half life of 40 days. The extent of accumulation of ribavirin following inhalation therapy is not well defined.

INDICATIONS AND USAGE:

Ribavirin aerosol is indicated in the treatment of carefully selected hospitalized infants and young children with severe lower respiratory tract infections due to respiratory syncytial virus (RSV). In two placebo-controlled trials in infants hospitalized with RSV lower respiratory tract infection, ribavirin aerosol treatment had a therapeutic effect, as judged by the reduction by treatment day 3 of severity of clinical manifestations of disease.[3,4] Virus titers in respiratory secretions were also significantly reduced with ribavirin in one of these studies.[4]

Only severe RSV lower respiratory tract infection is to be treated with ribavirin aerosol. The vast majority of infants and children with RSV infection have no lower respiratory tract disease or have disease that is mild, self limited, and does not require hospitalization or antiviral treatment. Many children with mild lower respiratory tract involvement will require shorter hospitalization than would be required for a full course of ribavirin aerosol (3 to 7 days) and should not be treated with the drug. Thus the decision to treat with ribavirin aerosol should be based on the severity of the RSV infection.

The presence of an underlying condition such as prematurity or cardiopulmonary disease may increase the severity of the infection and its risk to the patient. High risk infants and young children with these underlying conditions may benefit from ribavirin treatment, although efficacy has been evaluated in only a small number of such patients.

Ribavirin aerosol treatment must be accompanied by and does not replace standard supportive respiratory and fluid management for infants and children with severe respiratory tract infection.

Diagnosis:

RSV infection should be documented by a rapid diagnostic method such as demonstration of viral antigen in respiratory tract secretions by immunofluorescence[3,4] or ELISA[5] before or during the first 24 hours of treatment. Ribavirin aerosol is indicated only for lower respiratory tract infection due to RSV. Treatment may be initiated while awaiting rapid diagnostic test results. However, treatment should not be continued without documentation of RSV infection.

CONTRAINDICATIONS:

Ribavirin is contraindicated in women or girls who are or may become pregnant during exposure to the drug. Ribavirin may cause fetal harm and respiratory syncytial virus infection is self limited in this population. Ribavirin is not completely cleared from human blood even four weeks after administration. Although there are no pertinent human data, ribavirin has been found to be teratogenic and/or embryolethal in nearly all species in which it has been tested. Teratogenicity was evident after a single oral dose of 2.5 mg/kg in the hamster and after daily oral doses of 10 mg/kg in the rat. Malformations of skull, palate, eye, jaw, skeleton, and gastrointestinal tract were noted in animal studies. Survival of fetuses and offspring was reduced. The drug causes embryolethality in the rabbit at daily oral dose levels as low as 1 mg/kg.

WARNINGS:

Ribavirin administered by aerosol produced cardiac lesions in mice and rats after 30 and 36 mg/kg, respectively, for 4 weeks, and after oral administration in monkeys at 120 and rats at 154 to 200 mg/kg for 1 to 6 months. Ribavirin aerosol administered to developing ferrets at 60 mg/kg for 10 or 30 days resulted in inflammatory and possible emphysematous changes in the lungs. Proliferative changes were seen at 131 mg/kg for 30 days. The significance of these findings to human administration is unknown.

Ribavirin lyophilized in 6 gram vials is intended for use as an aerosol only.

PRECAUTIONS:

General:

Patients with lower respiratory tract infection due to respiratory syncytial virus require optimum monitoring and attention to respiratory and fluid status.

Drug Interactions:

Interactions of ribavirin with other drugs such as digoxin, bronchodilators, other antiviral agents, antibiotics, or antimetabolites has not been evaluated. Interference by ribavirin with laboratory tests has not been evaluated.

Carcinogenesis, mutagenesis, impairment of fertility:

Ribavirin induces cell transformation in an *in vitro* mammalian system (Balb/C3T3 cell line). However, *in vivo* carcinogenicity studies are incomplete. Results thus far, though inconclusive, suggest that chronic feeding of ribavirin to rats at dose levels in the range of 16-60 mg/kg body weight can induce benign mammary, pancreatic, pituitary and adrenal tumors.

Ribavirin is mutagenic to mammalian (L5178Y) cells in culture. Results of microbial mutagenicity assays and a dominant lethal assay (mouse) were negative.

Ribavirin causes testicular lesions (tubular atrophy) in adult rats at oral dose levels as low as 16 mg/kg/day (lower doses not tested), but fertility of ribavirin-treated animals (male or female) has not been adequately investigated.

Pregnancy:

Teratogenic Effects. Pregnancy Category X. See "Contraindications" section.

Nursing Mothers. Use of ribavirin aerosol in nursing mothers is not indicated because RSV infection is self limited in this population. Ribavirin is toxic to lactating animals and their offspring. It is not known whether the drug is excreted in human milk.

ADVERSE REACTIONS:

Approximately 200 patients have been treated with ribavirin aerosol in controlled or uncontrolled clinical studies.

Pulmonary function significantly deteriorated during ribavirin aerosol treatment in six of six adults with chronic obstructive lung disease and in four of six asthmatic adults. Dyspnea and chest soreness were also reported in the latter group. Minor abnormalities in pulmonary function were also seen in healthy adult volunteers.

Several serious adverse events occurred in severely ill infants with life threatening underlying diseases, many of whom required assisted ventilation. The role of ribavirin aerosol in these events is indeterminate. The following events were associated with ribavirin use:

Pulmonary: Worsening of respiratory status, bacterial pneumonia, pneumothorax, apnea, and ventilator dependence.

Cardiovascular: Cardiac arrest, hypotension, and digitalis toxicity.

There were 7 deaths during or shortly after treatment with ribavirin aerosol. No death was attributed to ribavirin aerosol by the investigators.

Some subjects requiring assisted ventilation have experienced serious difficulties, which may jeopardize adequate ventilation and gas exchange. Precipitation of drug within the ventilatory apparatus, including the endotracheal tube, has resulted in increased positive end expiratory pressure and increased positive inspiratory pressure. Accumulation of fluid in tubing ("rain out") has also been noted.

Although anemia has not been reported with use of the aerosol, it occurs frequently with oral and intravenous ribavirin, and most infants treated with the aerosol have not been evaluated 1 to 2 weeks post treatment when anemia is likely to occur. Reticulocytosis has been reported with aerosol use.

Rash and conjunctivitis have been associated with the use of ribavirin aerosol.

Overdosage:

No overdosage with ribavirin by aerosol administration has been reported in the human. The LD_{50} in mice is 2 gm orally. Hypoactivity and gastrointestinal symptoms occurred. In man, ribavirin is sequestered in red blood cells for weeks after dosing.

DOSAGE AND ADMINISTRATION

Before use, read thoroughly the Viratek Small Particle Aerosol Generator (SPAG) Model SPAG-2 Operator's Manual for small particle aerosol generator operating instructions.

Treatment was effective when instituted within the first 3 days of respiratory syncytial virus lower respiratory tract infection.[3] Treatment early in the course of severe lower respiratory tract infection may be necessary to achieve efficacy.

Treatment is carried out for 12-18 hours per day for at least 3 and no more than 7 days, and is part of a total treatment program. The aerosol is delivered to an infant oxygen hood from the SPAG-2 aerosol generator. Administration by face mask or oxygen tent may be necessary if a hood cannot be employed (see SPAG-2 manual). However, the volume of distribution and condensation area are larger in a tent and efficacy of this method of administering the drug has been evaluated in only a small number of patients. Ribavirin aerosol is not to be administered with any other aerosol generating device or together with other aerosolized medications. Ribavirin aerosol should not be used for patients requiring simultaneous assisted ventilation (see Boxed Warnings).

Virazole is supplied as 6 grams of lyophilized drug per 100 ml vial for aerosol administration only. By sterile technique, solubilize drug with sterile USP water for injection or inhalation in the 100 ml vial. Transfer to the clean, sterilized 500 ml widemouth Erlenmeyer flask (SPAG-2 Reservoir) and further dilute to a final volume of 300 ml with sterile USP water for injection or inhalation. The final concentration should be 20 mg/ml. **Important:** This water should not have had any antimicrobial agent or other substance added. The solution should be inspected visually for particulate matter and discoloration prior to administration. Solutions that have been placed in the SPAG-2 unit should be discarded at least every 24 hours and when the liquid level is low before adding newly reconstituted solution.

Using the recommended drug concentration of 20 mg/ml ribavirin as the starting solution in the drug reservoir of the SPAG unit, the average aerosol concentration for a 12 hour period would be 190 micrograms/liter (0.19 mg/l) of air.

HOW SUPPLIED:

Virazole® (ribavirin) Aerosol is supplied in 100 ml glass vials with 6 grams of sterile, lyophilized drug which is to be reconstituted with 300 ml sterile water for injection or sterile water for inhalation (no preservatives added) and administered only by a small particle aerosol generator (SPAG-2). Vials containing the lyophilized drug powder should be stored in a dry place at 15-25°C (59-78°F). Reconstituted solutions may be stored, under sterile conditions, at room temperature (20-30°C, 68-86°F) for 24 hours. Solutions which have been placed in the SPAG-2 unit should be discarded at least every 24 hours.

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citators except Hope 4 and PMR Bag meet the ASTM and ISO standards for minimum performance and safety. We recommend that the Hope 4 and PMR Bag not be used when an F_{DO_2} of 1.00 is needed. (OF-90-125)

Volume-Assisted Pressure Support Ventilation—Jorge Bonassa, Marcelo BP Amato MD, Carmem SV Barbas MD, Carlos RR Carvalho MD. Hospital Das Clinicas FMUSP, *Sao Paulo, Brazil.*

Pressure support ventilation (PSV) has become popular because of its usefulness in patient weaning. Decreased inspiratory work and improved synchrony between patient and ventilator is associated with PSV. The application of PSV in the CPAP mode requires that the patient have a reliable ventilatory drive because volume is patient-dependent at a set pressure-support level and no backup ventilation is available. If PSV is used in the SIMV or MMV modes, minimum ventilation requirements can be met by assist/control cycles, with additional flow and volume being supplied by a demand system. Activation of the demand system during assisted cycles requires the patient to drop tracheal pressure below baseline. **Method Description**: We propose a new method of ventilation in which pressure support is associated with conventional volume-assisted cycles. Whenever the patient activates an assisted cycle, the ventilator drives the preset controlled flow plus an additional demand flow through the demand system, as in conventional PSV. Both flow systems act together until the preset volume is achieved. If pressure support is not enough to deliver the preset volume, the controlled flow will do it. Pressure support will be volume-limited, rather than 25% of peak flow as in conventional PSV. Volume-assisted pressure-support (VAPS) cycles are intended to reduce inspiratory work when the patient, by his own effort, looks for supplementary flow during assisted cycles; this means better synchrony between patient and machine. **Method Evaluation**: To evaluate the performance of volume-assisted PSV, we created a simulation from a mathematical model. Simulated values are: resistance of endotracheal tube 10 cm $H_2O \cdot min \cdot L^{-1}$; resistance of patient circuit 5 cm $H_2O \cdot min \cdot L^{-1}$; compliance of lungs plus chest wall 0.1 L/cm H_2O; volume 1.0 L, controlled flow 40 L/min, and pressure support 15 cm H_2O. Inspiratory effort reflecting ventilatory muscle forces was simulated as a negative pressure mid-sine wave with duration of 1 second and amplitude variable from 0 to 30 cm H_2O. The work was measured to increase flow in order to reduce inspiratory time from 1.5 to 1.0 seconds with the same volume (1.0 L) in conventional assisted and VAPS cycles. **Results**: For simulated conditions, an addition of 15 cm H_2O of pressure support to the conventional assisted cycle caused a reduction of peak inspiratory effort from -27.5 to -10.0 cm H_2O to get additional flow through the demand system, reducing inspiratory time from 1.5 seconds to 1.0 second for a 1.0 L volume. Calculated work (area of inspiratory effort x volume curve) was 18.9 cm $H_2O \cdot L$ for assisted and 6.75 cm $H_2O \cdot L$ for VAPS cycles. **Conclusions**: Addition of pressure support to conventional assisted cycles reduces the inspiratory work required to get supplementary flow through the demand system. VAPS can be thought of as pressure-support cycles that are terminated by volume rather than by flow, which can be used in patients in the assist-control mode. PSV used with SIMV will not break the inspiratory pattern as occurs when backup ventilation is maintained by assisted cycles. (OF-90-047)

Volume-Assisted/Pressure-Supported Ventilation: Clinical Study—Marcelo Amato MD, Jorge Bonassa, Carmem S V Barbas MD, Carlos R R Carvalho MD. Hospital Das Clinicas Da FMUSP, *Sao Paulo, Brazil.*

This study reports the preliminary clinical evaluation of volume-assisted/pressure-supported ventilation (VAPSV). Briefly, at the same time that a preset positive inspiratory pressure with 'free' flow is offered (delivering exponentially decreasing flow through a demand system), a preset volume to the patient is ensured through a parallel circuit with conventional controlled inspiratory flow. Through mathematical simulation, we suspected that VAPSV, compared to conventional volume-assisted ventilation (VAV), would require less work to trigger supplementary demand flow. **Method**: Using a specially designed volume ventilator (INTER 7, Intermed Equipamento Medico Hospitalar Ltda, Sao Paulo, Brazil), five patients with acute respiratory failure (ARF) were studied. A 40-min period of VAV was followed by an equivalent period of VAPSV. At the end of each period, tracheal and esophageal pressures and inspiratory and expiratory flows were measured; blood gas analysis (F_{IO_2} = 1.00) was performed; and work of breathing per liter (WOB/L) during inspiration, pressure-time product, and inspiratory flow ($\dot{V}_I$) were calculated reflecting a 15-breath average. The two patterns of ventilation were also compared based upon estimates of dynamic compliance of the airways (C_{dyn}) and airway resistance (R_{aw}). **Results**:

Comparative Effects of VAV and VAPSV on Ventilatory Parameters*

	VAV	VAPSV
V_T (mL)	589 (79)	660 (92)†
PIP (cm H_2O)	38 (5)	38 (5)
$\dot{V}_I$ (L/min)	38.3 (3.8)	44.7 (5.3)
C_{dyn} (mL/cm H_2O)	19.3 (2.0)	22.0 (2.4)
R_{aw} (cm $H_2O \cdot s \cdot L^{-1}$)	51.4 (6.9)	44.5 (7.1)
WOB/L (J/L)	1.29 (0.60)	0.64 (0.30)
Pressure-Time Product (cm $H_2O \cdot s$)	9.5 (4.2)	4.7 (1.6)
P_{aO_2} (torr)	155 (42)	171 (44)

*All ventilatory parameters are shown as mean (SD).
†$p < 0.05$.

All studied ventilatory parameters improved with VAPSV, however, V_T was the only parameter to exhibit a statistically significant improvement ($p < 0.05$). **Conclusions**: The findings of this preliminary study suggest that VAPSV is a promising alternative to conventional volume-assisted ventilation for the treatment of unstable patients with ARF; however, further clinical evaluation with a larger sample size is needed to increase the power of the results and to confirm the efficacy of this new modality. (OF-90-164)

Comparison of Proximal Airway and Intralung Mean Airway Pressure during Positive-Pressure Ventilation in a Lung Model—George H Hicks MS RRT, John R Penwarden. Mt Hood Community College, *Gresham, Oregon.*

Recently it was shown that mean proximal airway pressure ($\bar{P}_{aw}$) is a very good predictor of mean intralung pressure ($\bar{P}_L$) in an infant animal model (Crit Care Med 1989;17:666). **Study Question:** Is $\bar{P}_{aw}$ an accurate indicator of $\bar{P}_L$ during variation of adult ventilator settings and lung conditions? **Methods**: A test lung (Michigan Instruments Inc, Grand Rapids MI), a 7200a ventilator (Puritan-Bennett, Overland Park KS), and a calibrated 1230a pressure monitor (Novametrix, Wallingford CT) were used to simulate adult mechanical ventilation and to measure $\bar{P}_{aw}$ and $\bar{P}_L$. Baseline ventilator settings (and adjustments) were: V_T 1.0 (0.25 to 1.5) L, f 15 (10 to 30) breaths/min, constant $\dot{V}$ 45 (20 to 120, sinusoidal and decelerating) L/min, I:E 1:2 (1:0.3 to 1:7.3), PEEP 0 (0 to 25) cm H_2O. Baseline simulated lung conditions (and adjustments) were: C_{st} 40 (20 to 80) mL/cm H_2O, and R_{aw} 14 (5 to 70) cm $H_2O \cdot s \cdot L^{-1}$. Conditions producing auto-PEEP were also simulated (f 30 breaths/min, and R_{aw} 24 cm $H_2O \cdot s \cdot L^{-1}$) and evaluated following correction by variations in $\dot{V}$ (60 to 120 L/min). One hundred-six pairs of $\bar{P}_{aw}$ and $\bar{P}_L$ were measured following equilibration of pressures after each adjustment from baseline settings. **Results**: The mean (SD) of the $\bar{P}_{aw}$ and $\bar{P}_L$ were 9.9 (6.7) and 9.5 (6.9) cm H_2O, respectively; and were found to be strongly correlated ($r = 0.9526$, $p < 0.0001$). The mean (SD) for $\bar{P}_{aw} - \bar{P}_L$ was 0.4 (1.6). Those conditions that resulted in a deviation > 2 cm H_2O above mean $\bar{P}_{aw} - \bar{P}_L$ ($n = 10$) were associated with increased $\dot{V}$ (> 80 L/min) and R_{aw} (> 25 cm $H_2O \cdot s \cdot L^{-1}$). Those conditions that resulted in a deviation < 2 cm H_2O below mean $\bar{P}_{aw} - \bar{P}_L$ ($n = 2$) were associated with inverse I:E (1:0.5) due to increased f (30 breaths/min). Conditions that produced auto-PEEP (8 cm H_2O) and then corrected by increased V produced the greatest increases in $\bar{P}_{aw} - \bar{P}_L$ (7.2 cm H_2O). **Conclusions**: These test lung data support the findings that $\bar{P}_{aw}$ is a precise predictor of $\bar{P}_L$ over a wide range of conditions simulating adult volume-limited ventilation. But, during high $\dot{V}$ and R_{aw}, $\bar{P}_{aw}$ will overestimate $\bar{P}_L$ and become an unreliable predictor despite changes in auto-PEEP. Use of inverse-ratio ventilation may also result in conditions that cause $\bar{P}_{aw}$ to underestimate $\bar{P}_L$ due to the degree of gas trapping. Further clinical studies are needed to confirm these findings. (OF-90-132)

Clinical and Laboratory Evaluation of the MAX Transport Ventilator—Jay A Johannigman MD, Richard D Branson RRT, Robert Campbell RRT, James M Hurst MD. University of Cincinnati Medical Center, *Cincinnati, Ohio.*

Background: Transport of critically ill, mechanically ventilated patients from intensive care units for diagnostic and therapeutic procedures has become common in the last decade. Maintenance of adquate oxygenation and ventilation during transport is mandatory. We evaluated the Hamilton MAX transport ventilator in the laboratory and in the clinical arena to determine its usefulness during inhospital transport. **Methods:** In the laboratory, we determined the MAX's ability to assure tidal volume (V_T) delivery in the face of decreasing compliance of a test lung, and we tested the alarm system. Using a two-compartment lung model modified to simulate spontaneous breathing, we also evaluated the responsiveness of the demand valve. The clinical evaluation was accomplished by comparing arterial blood gases and ventilator settings in the intensive care unit to those during transport. **Results**: As lung compliance was reduced from 0.1 to 0.02 L/cm H_2O, delivered V_T fell significantly at each set V_T. The alarm systems performed according to manufacturer's specifications. The demand valve triggered appropriately without positive end-expiratory pressure (PEEP), but as PEEP was increased, triggering became more difficult. The demand valve is referenced to ambient pressure and cannot compensate for elevated end-expiratory pressures. During patient transport, arterial blood gases were comparable to those achieved in the ICU. Because an inspired oxygen concentration of 1.0 was used during transport, arterial oxygenation (P_{aO_2}) was significantly greater (123 ± 75 vs 402 ± 85 torr). A higher ventilator rate was required during transport to prevent tachypnea (7 ± 3 vs 12 ± 6 breaths/min), and peak inspiratory pressure (PIP) was higher during transport (40 ± 8 vs 52 ± 11 cm H_2O). **Conclusions**: The MAX is a reliable transport ventilator, capable of maintaining adequate ventilation and oxygenation in a majority of mechanically ventilated patients. Care should be taken to assure adequate V_T delivery at high PIP, and ventilator rate may require adjustment to prevent tachypnea associated with triggering the non-PEEP-compensated demand valve when PEEP > 8 cm H_2O is used. (OF-90-139)

Easy Determination of Auto-PEEP on Ventilators Not Equipped with an Expiratory Hold—Chris Tyler MD, Neal Cohen MD, Jack Covington RRT, Ann Kniebel MSN RN. University of California at San Francisco, *San Francisco, California.*

Introduction: The determination of intrinsic, or unintended, positive end-expiratory pressure (auto-PEEP) has been shown to be useful in the management of patients requiring mechanical ventilation. Auto-PEEP can be easily measured with some ventilators; the Siemens 900C (S900C) ventilator is equipped with an expiratory hold button that facilitates the accurate and reliable measurement of auto-PEEP. Not all ventilators are so equipped. Measurement of auto-PEEP on such ventilators requires a simultaneous switch to the continuous positive airway pressure (CPAP) mode and manual occlusion of the expiratory port at the moment of the next anticipated inspiratory phase. For example, we have found the measurement of auto-PEEP on the Puritan-Bennett 7200 (PB7200) to be difficult and hard to reproduce between therapists primarily due to variations in the estimation of true end-expiration. This study describes and validates measurements of auto-PEEP obtained using a simple and inexpensive device. **Methods**: A Y-connector, one-way valve, and in-line manometer were inserted into the inspiratory limb of both the S900C and PB7200 ventilator circuits. Thede-

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vice diverts inspiratory flow away from the patient while the expiratory valve remains closed and thereby effectively reproduces the expiratory hold that is utilized by the S900C. The ventilators were connected to a test lung with predetermined volume and compliance characteristics. Airway resistance was adjusted to obtain low, moderate, and high levels of auto-PEEP. Simultaneous measurements of auto-PEEP were made on the S900C using the expiratory hold button of the ventilator (Exp Hold) and a calibrated strip-chart recorder and then compared with measurements from the manometer/Y-connector device inserted into the circuit. A parallel experiment compared device and recorder on the PB7200. Eight determinations of auto-PEEP were obtained for both ventilators at each level of auto-PEEP. **Results**: The values for auto-PEEP on the S900C ventilator obtained by the in-line device and strip-chart recorder were not statistically different from the values for auto-PEEP obtained by utilizing the expiratory-hold button on the ventilator (Dunnett t test, $p > 0.05$). The auto-PEEP levels measured on the PB7200 with the in-line device correlated closely with those on the strip-chart recorder.

Measured Auto-PEEP*

	S900C			PB7200	
	Exp Hold	Device	Recorder	Device	Recorder
High Auto-PEEP	22 (0)	23 (0)	23.2 (0.07)	23 (0.57)	22.6 (0.41)
Moderate Auto-PEEP	10 (0)	10.8 (0.14)	11.8 (0.14)	8 (0)	7.9 (0.05)
Low Auto-PEEP	4 (0)	3.4 (0.20)	4.1 (0.03)	4 (0)	4.4 (0.05)

* Measurements are mean (SE) in cm H_2O.

Conclusions: We conclude that the auto-PEEP values obtained using this device are equivalent to the values determined by the S900C expiratory-hold function. The use of this device allows simple and reliable determination of auto-PEEP for patients ventilated with the PB7200 ventilator, and we currently use it routinely for this purpose in our ICU. Additional studies are underway to confirm the reliability of auto-PEEP measurement over a wide range of airway resistance, lung compliance, and inspiratory times for other ventilators not equipped with expiratory hold. (OF-90-031)

Compression Volume in Adult Ventilator Circuits—Sandy McCurdy, Dean Hess MEd RRT, Mark Simmons MS RRT RPFT. York Hospital, *York, Pennsylvania.*

We compared the compression volume of five adult disposable ventilator circuits and a nondisposable MA-1 circuit. **Method**: Five brands of disposable circuits (Inspiron, Intertech, Marquest, Seamless, and U-Mid) and one nondisposable brand (Bennett MA-1) were used. Circuits were attached to an MA-1 ventilator in the standard manner, except that the humidifier was bypassed to eliminate its contribution to compressible volume. The ventilator delivered a 1-L volume to a Michigan Instruments TTL Test Lung at a flow of 60 L/min and a rate of 12/min. A valve system (Instrumentation Industries RI 27-142) was placed between the Y-connector and the TTL to partition circuit compression volume from the volume delivered to the test lung. The compression factor was calculated by dividing the compressible volume by the ventilating pressure. Five compliance settings were used on the TTL (0.1, 0.05, 0.03, 0.02, 0.015 L/cm H_2O) to simulate different ventilating pressures. Pressure at the Y-connector, compressible volume, and volume delivered to the TTL were measured using a calibrated Timeter RT200. Five measurements were made with each brand. A new circuit was used for each run with a disposable circuit, and a different circuit from the respiratory care department stock was used for each run with an MA-1 circuit. Our methodology was similar to that of a previously published study (Crit Care Med 1985;13:851-854). **Results**:

Compression Factors* for the Circuits Evaluated

	TTL compliance setting				
	0.1	0.05	0.03	0.02	0.015
Inspiron	1.5 (0.03)	1.6 (0.2)	1.8 (0.1)	2.0 (0.02)	1.9 (0.1)
Intertech	2.3 (0.3)	2.4 (0.2)	2.5 (0.1)	2.5 (0.1)	2.6 (0.0)
Marquest	1.4 (0.3)	1.9 (0.1)	2.0 (0.2)	2.1 (0.1)	2.1 (0.0)
Seamless	1.7 (0.2)	2.1 (0.2)	2.0 (0.1)	2.2 (0.0)	2.0 (0.1)
U-Mid	1.8 (0.3)	2.0 (0.2)	2.1 (0.1)	2.2 (0.01)	2.2 (0.1)
MA-1	1.6 (0.1)	1.5 (0.1)	1.4 (0.1)	1.4 (0.2)	1.4 (0.1)

*All values are mean (SD) in mL/cm H_2O

There were significant differences between the compression factors at different compliance settings ($p < 0.001$ by ANOVA), and brands of circuits evaluated ($p < 0.001$ by ANOVA). **Conclusions**: There are differences in circuit compression factors as a function of the ventilating pressure and the brand of circuit. These differences should be considered when low tidal volumes and high pressures are used. Although these differences are too small to be clinically important in many cases, they may be important during ventilation with low tidal volumes and high pressures. (OF-90-038)

Evaluation of the Fenem End-Tidal CO_2 Detector during In-Hospital Patient Transport—Ann Daugherty BS RRT, Dean Hess MEd RRT, David Eitel MD, Mark Simmons MS RRT RPFT. York Hospital, *York, Pennsylvania.*

A disposable device, the FEF End-Tidal CO_2 Detector (Fenem Airway Management Systems, New York NY), produces a color change due to CO_2 in the exhaled gas. Absence of CO_2 (< 0.5%) produces a purple color, 2% to 5% produces a yellow color, and 0.5% to 2% produces an intermediate color. The color of the indicator is compared to a reference color on the dome of the device. The principal application of this device is to verify correct endotracheal tube placement. In this study, we evaluated the usefulness of this device during inhospital transport of mechanically ventilated patients. **Methods**: All patients were hemodynamically stable, and were transported between the ICU and a special procedures area such as the radiology department. Ventilation was provided by a respiratory therapist, who used a bag-valve device during transport, and a transport ventilator during special procedures (such as CT scanning). The FEF device was placed between a heat-moisture exchanger and the ventilation device. Cyclic inspiratory-expiratory color change was noted at 5-min intervals. Adverse conditions during transport (such as endotracheal tube dis-

placement or ventilator disconnect) and associated FEF-device color changes were also noted. **Results**: The device was used in 24 patients (12 female, 12 male, mean [SD] age 36 [18] years) during 30 transports (mean [SD] duration 58 [23] min). The patients' mean (SD) systolic blood pressure was 131 (21) torr, mean (SD) heart rate was 93 (20) beats/min, and mean (SD) P_{aCO_2} was 30 (5) torr. Cyclic color changes were produced by the FEF device throughout each transport, but were more easily detected with the transport ventilator than with the bag-valve device. The ventilator tubing became disconnected during the CT scan of one apneic patient, which was first detected by the respiratory therapist who noted that the cyclical color changes on the FEF device ceased. This resulted in prompt correction of the problem and no adverse sequelae for the patient. No other airway or ventilatory problems occurred during any of the transports. **Conclusions**: With proper supervision by a respiratory therapist, airway and ventilatory problems during in-house transport of mechanically ventilated patients are rare. In apneic, unstable mechanically ventilated patients, the FEF device may be useful in the detection of ventilator disconnection and airway misplacement. Further work is needed to evaluate the role of the FEF device during intrahospital and interhospital patient transport. (OF-90-046)

A Comparison of Two Methods of Preoxygenation during Endotracheal Suction—Arthur A Taft MHS RRT, Shelley C Mishoe MEd RRT, Franklin H Dennison MEd RRT, David C Lain PhD RRT, Bashir A Chaudhary MD. Medical College of Georgia, *Augusta, Georgia.*

A new, single-lumen oxygen-insufflation catheter (VenTech ISC), designed to alternately deliver oxygen or suction, was evaluated to determine if it could prevent episodes of hypoxemia during endotracheal suction. (No other study has been published using a single-lumen insufflation catheter in an adult sample.) **Method**: Insufflation-catheter suctioning was compared to the conventional resuscitation-bag method of suctioning in 23 intubated adult patients (F_{IO_2} ranging from 0.30 to 0.50) from the medical, trauma, and neurological ICUs. Patients were selected for the study if we were able to obtain informed consent and if they met the criteria: were intubated with a ≥ 7.5 mm ID endotracheal tube, had an arterial cannula, and were on < 10 cm H_2O of PEEP. All suctioning procedures consisted of two suction passes with 10 s of continuous suction at -120 torr. The conventional method used a resuscitation bag to deliver five breaths of 100% O_2 (pre- and post-suctioning). The insufflation method consisted of delivering 15 L/min O_2 through the catheter for 15 s prior to suctioning, reconnecting the patient to the ventilator for 30 s after suctioning, and then repeating the procedure. Each subject served as his/her own control and was randomly assigned as to which method was used first. The P_{aO_2} and S_{aO_2} were recorded for each method prior to suctioning and at 30, 60, and 180 s following the procedure. **Results**: Using insufflation, mean P_{aO_2} decreased a maximum of 2 ± 17 torr (mean ± SD) from a baseline of 106 (± 30) torr and mean S_{aO_2} decreased a maximum of 0.4 (± 0.7%) from a baseline of 95.5 (± 1.5%). When using insufflation, if the patient's baseline P_{aO_2} was > 95 torr, the mean P_{aO_2} decreased from 130 (± 21) to 123 (± 32) torr; however, if the baseline P_{aO_2} was < 95 torr, the mean P_{aO_2} increased from 80 (± 8) to 84 (± 11) torr. Using bagging, mean P_{aO_2} increased a maximum of 38 (± 37) torr from a baseline of 106 (± 35) torr and mean S_{aO_2} increased a maximum of 1.0 (± 2.2%) from a baseline of 95.4 (± 2.2%). ANOVA for repeated measures revealed a significant interaction between preoxygenaton method and time for both P_{aO_2} and S_{aO_2} ($p < 0.001$). Oxygen insufflation prevented a clinically significant change from baseline in mean P_{aO_2} and S_{aO_2} at all sampling times, while bagging increased mean P_{aO_2} and S_{aO_2}. **Conclusions**: This study suggests that in patients meeting the above criteria adequate arterial oxygenation can be maintained during suctioning using a single-lumen oxygen-insufflation catheter. Further studies are needed to determine the optimal oxygen insufflation flowrates to use during endotracheal suctioning and to assess the efficacy of this alternative suctioning method in more-severely-impaired mechanically-ventilated patients on high levels of PEEP. (OF-90-026)

An Evaluation of the Effectiveness of Secretion Removal with a Closed-Circuit Suction Catheter—Mary Tuleya Witmer RRT, Dean Hess MEd RRT, Mark Simmons MS RRT RPFT. York Hospital, *York, Pennsylvania.*

Closed-circuit suction catheters are used to avoid arterial oxygen desaturation during suctioning when high levels of PEEP and F_{IO_2} are used. It has been the impression of the critical care therapists and nurses at our hospital that the closed-circuit catheter is less effective than a conventional suction catheter in the removal of secretions. In this study, we compared the quantity of secretions removed with a closed-circuit catheter (Ballard, Midvale UT) to that of a conventional catheter (Pharmaseal, Valencia CA). In our opinion, the Ballard catheter is representative of other closed-circuit catheters on the market and the Pharmaseal is representative of other conventional catheters available on the market. **Methods**: Only adult patients were included in this study, and all had a physician's order for chest physiotherapy at 4- or 6-h intervals. For two consecutive treatments, the patients were suctioned with a Ballard closed-circuit catheter during one chest physiotherapy treatment, and with a conventional catheter during the other treatment. The order in which the catheters were used was randomly assigned, and both were used on the same day shift. In all cases, 14-Fr suction catheters were used; and the same suction pressures (120 torr) were used with the closed-circuit and the conventional suction catheters. Saline lavage was not used during suctioning with either catheter. All sputum obtained during each chest physiotherapy treatment was collected in a Lukens trap, and the mass of the secretions was determined using an O-Haus Cent-O-Gram balance. **Results**: A total of 28 comparisons of the Ballard and the standard catheter were made in 25 patients (16 men, 9 women, median age 59 y, median 8 days of intubation). Seven of the patients had tracheostomy tubes, and

the others had endotracheal tubes. The mean PEEP level was 3 cm H_2O (range 0-10 cm H_2O) and the mean F_{IO_2} was 0.45 (range 0.30-0.80). There was no significant difference between the quantity of secretions removed with the Ballard closed-circuit catheter (median 1.7 g) and the conventional catheter (median 1.9 g) ($p = 0.88$ by Wilcoxon matched-pairs test). **Conclusions**: The results of this study suggest that the Ballard closed-circuit suction catheter removes secretions as effectively as does a conventional suction catheter. Because this study was limited to short-term use, further work is necessary to evaluate the effectiveness of the closed-circuit catheter during prolonged use. Further work is also needed to compare the cost of using closed-circuit catheters to the cost of using conventional catheters. (OF-90-045)

Comparison of the Jinotti Oxygen-Insufflation Catheter to Standard Hyperoxygenation Techniques in Patients on High F_{IO_2} and High PEEP—Michael S Friel RRT, University Medical Center; Stuart F Quan MD, University of Arizona Health Sciences Center; Susan M Lohse RRT, University Medical Center—*Tucson, Arizona.*

In this study we sought to determine whether the Jinotti Oxygen-Insufflation Catheter System (American Pharmaseal, Valencia CA) is capable of attenuating oxygen desaturation (< 90%) during suctioning as efficiently as standard hyperoxygenation techniques. **Materials & Methods**: In 4 patients, the Jinotti system was compared to standard hyperoxygenation techniques: disconnection from the ventilator with subsequent manual hyperinflation using 100% O_2 and a resuscitation bag, or increasing the F_{IO_2} to 1.0 on the ventilator and introducing an Argyle-tip suction catheter through a Bodai swivel (Sontek Medical, Hingham MA). The Jinotti system incorporates a dual-lumen 14-FRr catheter with one lumen providing suction and the other providing O_2 insufflation at 7 L/min. The suction for both the Jinotti and standard suctioning methods was set at -120 torr. Nine points of measurement were selected: 1 min prior to suctioning; at the start of, during, and following a 15-s suction pass; after 1 min of reoxygenation; at the start of, during, and following a repeat 15-s suction pass; and 5 min after a final reoxygenation period. Prior to suctioning, mean (SD) F_{IO_2} was 0.59 (0.05) and mean (SD) PEEP was 12.5 (2.6) cm H_2O. Each patient served as his/her own control. The comparison of the suctioning methods was completed within a 4-h interval. Saturation and pulse rate were recorded on a dual strip-chart recorder. Heart rate and blood pressure measurements were simultaneously recorded so that pulse rate correlation and hyper-/hypotensive episodes occurring during the study could be observed. **Results**: Mean (SD) saturations were 94 (1.7) % for the Jinotti-system method and 95 (1.7) % for the standard hyperoxygenation method. A two-tailed pooled *t* test was done to determine whether any significant difference ($p < 0.05$) existed between the two methods. The *t* value equaled 0.0002328, the critical *t* value equaled 3.182 for $p < 0.05$; therefore the null hypothesis was accepted. **Conclusions**: There was no significant difference between the two methods with respect to attenuation of oxygen desaturation during suctioning. The Jinotti system may promote conservation of manpower in hospitals because a second caregiver is not required to provide hyperoxygenation between suction passes. (OF-90-118)

Selected Topics in Neonatal and Pediatric Practice

The Smoking Status and Attitudes Towards Smoking of Middle School Students—Barbara Swindler BS CRTT, Dean Hess MEd RRT, Mark Simmons MS RRT RPFT, York Hospital; David Wilson MEd, Lisa Marriott BS, American Lung Association of South Central Pennsylvania; Krista DeRolf, York Hospital—*York, Pennsylvania.*

The importance of anti-smoking programs among school children has become increasingly recognized in recent years. We conducted this study in south central Pennsylvania with our local Lung Association to evaluate the smoking status and attitudes towards smoking of middle school students (Grades 6-8). **Methods**: A rural school (679 students), an urban school (665 students), and a suburban school (337 students) participated in the study. There were 853 boys and 828 girls. A questionnaire was developed to assess the students' attitudes toward smoking; it was adapted from previously used questionnaires designed for this purpose. Questionnaires were completed by the students during homeroom, and the completed questionnaires were returned in a sealed envelope. Overall, 82.6% of the students enrolled in these middle schools participated. The students were assured that confidentiality of results would be maintained, and that the results would be used only for research purposes. The data were analyzed using cross-tabulation and chi-square analysis. **Results**: Overall, 10.3% of the students were smokers. Smoking was more prevalent in girls (11.4%) than in boys (9.3%), but this was not statistically significant ($p = 0.16$). The percentage of smokers increased with grade level; 5.7% of sixth graders smoked, 9.7% of seventh graders smoked, and 15.4% of eighth graders smoked ($p < 0.0001$). There were significant differences in the percentage of smokers between the schools ($p < 0.0001$); 16.9% of students in the suburban school smoked, 11.9% of students in the urban school smoked, and 5.4% of students in the rural school smoked. Smoking among students was significantly more prevalent when one or both of the parents smoked (13.6%) than when neither parent smoked (6.4%) ($p < 0.0001$). There was no significant difference in the percentage of smokers among Whites (10.1%), Blacks (8.5%), and Hispanics (12%) ($p = 0.60$). Nonsmokers were more likely to believe that smoking causes illness ($p < 0.0001$) and death ($p = 0.008$). Nonsmokers were also more likely to believe that smoking is addictive ($p < 0.001$). **Conclusions**: Our results indicate that anti-smoking programs should target Whites, Blacks, and Hispanics equally. The differences among school systems indicates that greater resources for anti-smoking programs should be targeted at suburban schools than rural or urban schools. Smokers tended not to appreciate the health effects of smoking; therefore, when anti-smoking programs are provided for this age group, consideration should be given to emphasizing these effects. Because many students begin smoking by the time they reach middle school, anti-smoking programs should begin in the elementary schools. (OF-90-037)

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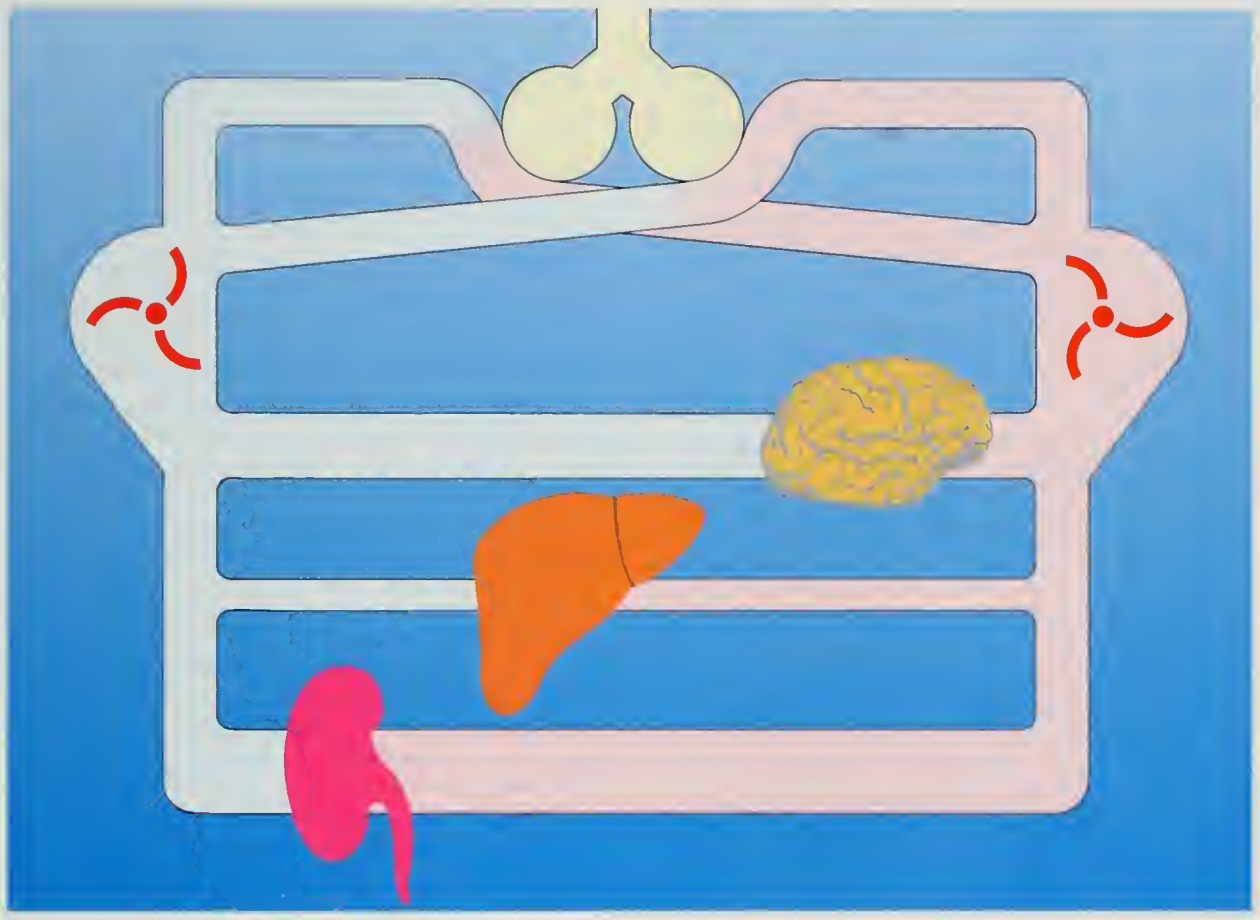

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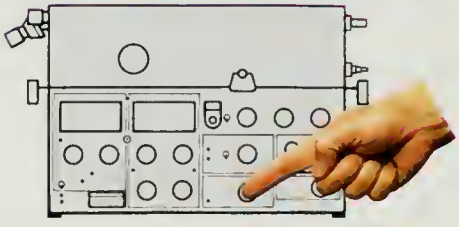

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Gastric Feeding during Nasopharyngeal CPAP Is Well Tolerated in Neonates—Jamie Clink RRT, Gregg Lund DO, Neel B Ackerman MD. Presbyterian Hospital of Dallas, *Dallas, Texas.*

Nasopharyngeal CPAP (NPCPAP) is a widely used therapy in neonatal intensive care. A paucity of data exists on the safety of enteral feeding during this therapy. We retrospectively evaluated our experience with gastric feedings of neonates receiving NPCPAP at our institution from June 1988 to March 1990. **Method**: All NPCPAP was delivered via nasally inserted endotracheal tubes of appropriate size, placed at the level of the soft palate. An orogastric feeding tube (open to atmospheric pressure) was continuously present. All feeds were by gravity and the orogastric tube was clamped for 20 min following the feeding. **Results**: 13 patients (17 courses of NPCPAP) were included in our retrospective evaluation. Mean (SD) gestational age and weight of the infants at birth was 27 (4.7) weeks and 1,027 (754) g, respectively. Mean (SD) gestational age, weight, and postnatal age of the infants at the onset of NPCPAP was 32 (4.8) weeks, 1,272 (713) g, and 42 (20.9) days, respectively.

Course on NPCPAP

Duration (days)	Total # feeds	% tolerated feeds	Enteral calories (Cal/kg/day)	Wt gain (g/day)
6.4(4.4)*	50 (36)	98.6 (2.8)	103 (90.9)	16 (32.8)

* All values are mean (SD).

There were no episodes of aspiration (proven or suspected), nor was it necessary to discontinue NPCPAP because of feeding difficulties. **Conclusion**:The findings of our retrospective study suggest that neonates treated with NPCPAP may be fed adequately via the orogastric route. (OF-90-050)

High-Frequency Oscillatory Ventilation in Persistent Air Leak: A Pediatric Case Study—Theresa A Reno RRT, James C Cunningham MD. Cook-Fort Worth Children's Medical Center, *Fort Worth, Texas.*

Case Summary: A 14-month 8.5-kg girl suffered a near-drowning incident and subsequent aspiration pneumonitis with development of respiratory failure. She did well on conventional mechanical ventilation (CV) for the first 24-36 hours, at which time her condition deteriorated. She developed persistent air leaks, including pneumothorax and pneumomediastinum. She could not be adequately oxygenated despite an F_{IO_2} of 1.0, SIMV 27 breaths/min, PEEP 22 cm H_2O, V_T 150 mL (17.6 mL/kg). These settings resulted in a PIP of 76 cm H_2O, $\bar{P}_{aw}$ 25 cm H_2O, arterial pH 7.28, P_{aCO_2} 49 torr, and P_{aO_2} 73 torr. Due to persistent air leak syndrome and continued deteriorating pulmonary status, permission was requested and granted for compassionate use of the SensorMedics 3100 High-Frequency Oscillatory Ventilator (HFOV). Her clinical condition was further complicated by a significant pneumoperitoneum that was felt to be impeding movement of her diaphragm and compromising ventilation. A decompression tube was placed in the abdomen. HFOV stabilization on settings of $\bar{P}_{aw}$ 40 cm H_2O, ΔP (peak-trough airway pressures) 90 cm H_2O, T_I 40% of total cycle time, f 8 Hz, and F_{IO_2} 1.0 resulted in marked improvement in arterial pH and blood gas values (pH 7.35, P_{aCO_2} 48 torr, P_{aO_2} 227 torr) and hemodynamic status. Over the next several days, there was continued clinical improvement and progressive resolution of all air leaks. After 8 days on HFOV, she had improved enough to be placed back on CV. In a few days, she was weaned successfully from mechanical ventilation. At pulmonary follow-up 6 weeks post-incident, S_{pO_2} was 97%, chest radiograph was normal, and she had no pulmonary symptoms. **Conclusion**: HFOV provided adequate oxygenation and ventilation while effectively managing persistent air leak syndrome in this patient. However, further clinical study is needed to confirm the efficacy of using HFOV in the management of persistent air leak syndrome. (OF-90-138)

Dilution of Blood Gas Samples from Radial and Umbilical Arterial Lines—Robert M Lewis BA RRT. The Children's Memorial Hospital, *Chicago, Illinois.*

The use of radial arterial (RA) lines has been advocated in the newborn to avoid the complications associated with umbilical arterial (UA) lines. Because flushing of these lines is hazardous, the "3-drop" method (in which 3 drops of blood and flush solution are spilled prior to collecting the sample) has been advocated to minimize blood loss and dilution from the continuous flush solution. Good correlation (r) has been established between the 3-drop method and the conventional technique that requires withdrawing two or more mL of blood. However, a statistically significant r between samples drawn on the same patient may mask clinically important errors due to dilution in a small portion of samples. Moreover, assessing the quality of samples drawn from RA lines by using the patient as his/her own control is not practical as an ongoing quality assurance monitoring tool. If blood gas samples are diluted, there will be a change in the measured hemoglobin. Therefore, I determined the rate of hemoglobin variability in blood gas samples from patients with RA lines, and compared this to the hemoglobin variability in blood gas samples drawn from patients with UA lines. **Methods & Results**: All blood gas analyses performed in our NICU during a one-month period were reviewed. The number of blood gas samples with a measured hemoglobin that differed by more than 1 g from the previous sample was determined. Evidence of dilution was present in 36/89 (40%) of the RA samples and in 9/103 (9%) of the UA samples ($p < 0.005$, chi-square). Using the same methods, I was able to determine the effects of educational intervention on sample dilution. After instructing staff on correct procedures for RA sampling, the rate of sample dilution fell to 30% (40/133) in RA samples ($p < 0.005$, pre/post educational intervention), and remained constant at 10/104 (10%) for UA ($p < 0.005$, RA vs UA). **Conclusions**: A significantly higher percentage of blood gas samples from RA lines are diluted than from UA lines, even with training reinforcement. Determining hemoglobin variability for RA samples, using concurrent data from patients with UA lines as a control, is a useful technique for monitoring blood-gas sample quality in the NICU. (OF-90-089)

The Effect of Oxicap 4700 End-Tidal CO_2 Analyzer Sampling Rate on Tidal Volume Delivered by a Volume Ventilator to an Infant Lung Model—John W Salyer RRT, Bill Henry RRT, Howard Christie RRT, Robert L Chatburn RRT. Rainbow Babies and Childrens Hospital, *Cleveland, Ohio.*

Different brands of sidestream end-tidal CO_2 ($etCO_2$) analyzers aspirate gas from the proximal airway at various rates. The sampling rate has a potential effect on the delivered tidal volume (V_T), especially when ventilating small pediatric patients with a volume ventilator. **Research Question**: What is the effect of sampling rate on V_T when using an Oxicap 4700 sidestream $etCO_2$ analyzer (Ohmeda, Louisville CO). **Methods**: We assembled a model of a patient-ventilator system using a Servo 900C (Siemens-Elema Inc, Schaumburg IL), an infant test lung (Infrasonics Inc, San Diego CA) with compliance (C) = 1.0 mL/cm H_2O, and a neonatal disposable ventilator circuit (Isothermal Inc, Riverside CA) with C = 1.0 mL/cm H_2O. V_T was measured with a StarCalc computerized pneumotachograph system (Infrasonics Inc), with and without the $etCO_2$ analyzer in-line. The StarCalc was calibrated and operated according to the manufacturer's recommendations. Measurements were made for 20 breaths, and volume was reported as a mean of these 20 breaths. Data were subjected to two-tailed *t* tests and significance was established at $p < 0.05$. The Oxicap 4700 reportedly aspirates gas at 300 mL/min from the circuit at the proximal airway by a sidestream configuration. Experimental conditions were: f 20 breaths/min, working pressure 60 cm H_2O, PEEP 0 cm H_2O, I:E 1:2, set V_T 50 mL. **Results**: Mean (SD) measured V_T before and during the use of the $etCO_2$ analyzer was 32.5 (1.3) mL and 26.7 (1.1) mL, respectively ($p = 0.0001$). **Conclusions**: We observed a statistically significant decrease in delivered V_T under these test conditions when the Oxicap 4700 sidestream $etCO_2$ analyzer was utilized with a sampling rate of 300 mL/min. It is reasonable to assume that this effect will decrease as set tidal volume increases and, thus, should only be a concern in small pediatrics patients. This drop in volume can easily be compensated for by increasing the set tidal volume. (OF-90-122)

The Effect of Continuous In-Line Nebulization on Tidal Volume during Volume Ventilation of an Infant Lung Model—John W Salyer RRT, Bonnie Rosolowski RRT, Lee O'Loughlin RRT, Robert L Chatburn RRT. Rainbow Babies and Childrens Hospital, *Cleveland, Ohio.*

Research Question: What is the effect on tidal volume (V_T) of placing a continuous nebulizer in line when ventilating an infant lung model with a volume ventilator? **Methods**: We used a Servo 900C (Siemens-Elema Inc, Schaumburg IL), an infant test lung (Infrasonics Inc, San Diego CA) with compliance (C) = 1 mL/cm H_2O, and a neonatal disposable ventilator circuit (Isothermal Inc, Riverside CA) with C = 1 L/min. A nebulizer was placed in-line on the inspiratory limb and operated at 5 L/min. Flow, volume, and pressure were measured at the proximal airway with a StarCalc computerized pneumotachograph system (Infrasonics Inc), with and without the nebulizer in-line. The StarCalc was calibrated and operated according to the manufacturer's recommendations. Measurements were made for 20 breaths, and volume was reported as a mean of these 20 breaths. Data were subjected to two-tailed *t* tests, and significance was established at $p < 0.05$. Experimental conditions were: f 20 breaths/min, PEEP 0 cm H_2O, working pressure 60 cm H_2O, I:E = 1:2, and set V_T 50 mL. **Results**: Mean (SD) measured V_T before and during nebulizer operation was 31.6 (1.2) mL and 73.3 (0.6) mL, respectively ($p = 0.0001$). Mean (SD) PIP before and during nebulizer operation was 22.6 (0.9) cm H_2O and 56.6 (0.2) cm H_2O, respectively ($p = 0.0001$). **Conclusion**: Continuous in-line nebulization during small-volume ventilation of an infant lung model, using the Servo 900C, results in statistically significant and clinically important increases in PIP and V_T. This occurs because the nebulizer adds volume to the ventilator circuit during inspiration. Overdistention of the lung is possible if care is not taken when in-line nebulization is being provided. A possible solution is to place the nebulizer at the outlet of the humidifier and to nebulize only during exhalation, thus filling the inspiratory limb with aerosol-laden gas to be delivered to the patient, but avoiding the addition of volume to the circuit during the inspiratory phase (J Aerosol Med 1989;2:339- 347). (OF-90-120)

A Comparison of Two Different Endotracheal-Tube Taping Techniques in the Neonate—Thomas J Kallstrom RRT, John W Salyer RRT, Karen K Baldesare RN RRT, Robert L Chatburn RRT. Rainbow Babies and Childrens Hospital, *Cleveland, Ohio.*

We compared two techniques for securing neonatal endotracheal tubes (ETTs) and their effect on the rate of accidental extubation (AE) over a period of 3 consecutive months. **Methods**: During an initial 2-month control phase, ETTs were secured with tincture of benzoin and cloth adhesive tape, and data were gathered with respect to the incidence of AE and related events. Then, during the 1-month experimental phase, ETTs were secured using tincture of benzoin and a combination of elastic adhesive and cloth adhesive tape, and the same data were gathered. All intubations were orotracheal. Chi-square analysis was used to compare the characteristics of patients in both phases as well as the rates of AE. Significance was established as $p < 0.05$. **Results**: Results are shown below.

Comparative Data between ETT-Taping Method Phases

	Phase I (control)	Phase II (experimental)	p value
Number of:			
ventilator days	777	309	
total patients	87	37	
patients with 2.5 ETT	23 (26%)	10 (27%)	0.40
patients with 3.0 ETT	40 (46%)	13 (35%)	0.40
patients with 3.5 ETT	21 (24%)	12 (32%)	0.40
patients with 4.0 ETT	3 (3%)	2 (6%)	0.40
AEs	60	17	0.0001
AE/100 ventilator days	7.7	5.5	
Percentage of AEs that occurred:			
while suctioning	1%	18%	
with tubing support	7%	76%	
with patient's head immobilized	2%	18%	
with tape secure at time of AE	2%	0%	

Discussion: The distribution of ETT sizes in both phases was not significantly different. The rate of AE was significantly lower during the experimental phase, suggesting that the use of elastic and cloth adhesive tape reduces the incidence of AE when compared to the use of cloth adhesive tape alone. The fact that a low percentage of AEs occurred while the patient's head was immobilized suggests that this may play an important role in preventing AE, although the design of our study does not allow us to establish a cause and effect relationship between these variables. The high percentage of AEs that occurred in spite of the use of ventilator tubing supports was surprising because this practice is regarded as important in the prevention of AEs. Our findings also suggest that suctioning is implicated as an important factor in the occurrence of AE in the neonatal intensive care unit. **Conclusion:** Although, many factors are associated with the occurrence of accidental extubation in the neonate, our findings suggest that use of elastic and cloth adhesive tape may reduce incidence of AE compared to use of cloth adhesive tape alone. (OF-90-121)

A New Method for Attaching Nasal CPAP Prongs to Premature Infants—Henry A Ruiz RRT. University of Virginia Health Sciences Center, *Charlottesville, Virginia.*

Continuous positive airway pressure through nasal prongs (nasal CPAP) is an accepted form of therapy used to treat infant respiratory distress syndrome in premature infants. However, firm attachment of nasal-CPAP devices has remained a clinical problem. Several attachment devices have been developed, but problems are associated with their use: difficulty in securing and removing the devices from the infant, inability to gain quick access to the infant's head or airway, and risk of intracranial hemorrhage resulting from use of constrictive bands. A new attachment method was developed and tested at my institution. **Materials & Method**: A cotton fabric ribbon is threaded through the conventional CPAP device and secured to two small 'hook-and-loop' patches attached with nonallergenic adhesive to the zygomatic arches of the infant's face. After a 4-month trial period, during which time the attachment method was further refined, the new method was implemented universally in our neonatal ICU and evaluated for 8 months on 106 patients. To assess the efficiency and safety of the new method, a user survey was conducted; questionnaires were distributed to the 81 members of the neonatal team: 7 RCPs, 5 physicians, and 69 nurses. The questionnaire required the team members to evaluate the new method on the basis of: (1) visual and physical access, (2) ease of application, (3) stability on the patient, (4) skin damage, and (5) overall performance. **Results**: 37/81 questionnaires were completed and returned (47% response rate); 7/7 RCPS (100%) , 3/5 physicans (60%), and 27/69 nurses (39%) completed and returned the questionnaires. The new method was rated as follows: (1) visual and physical access—very difficult 0%, somewhat difficult 5.4%, little trouble 21.6%, easy 51.4%, and very easy 21.6%; (2) ease of application—very difficult 0%, somewhat difficult 0%, little trouble 22.3%, easy 58.3%, and very easy 19.4%; (3) stability on patient—no stability 0%, poor stability 2.7%, moderate stability 43.2%, good stability 43.3%, and very stable 10.8%; (4) skin damage—necrosis, blistering, etc 2.7%, very tender and red 0%, moderate tissue redness 25%, very little redness 55.6%, and no indication of skin breakdown 16.7%; (5) overall performance—poor 0%, fair 2.6%, good 29%, very good 55.2%, and excellent 13.2%. **Conclusion**: The findings suggest that this new method for securing CPAP devices is well accepted by neonatal staff and that it eliminates many of the identified difficulties associated with other devices and methods. This simple, inexpensive new method is now routinely used at my institution. (OF-90-130)

Evaluation of a New Negative-Pressure Device for the Treatment of Neonatal Respiratory Disease—Martha B Smith MPH RRT, David Easa MD, Jacqueline S Davis BS RRT, Cynthia A Sundquist RRT, Wendell T Inouye BA RRT. Kapiolani Medical Center for Women & Children, *Honolulu, Hawaii.*

Previously, the method of delivering extrathoracic negative pressure to sick newborn infants with pulmonary diseases utilized a negative-pressure isolette developed by the Air Shields Corporation. However, problems have been encountered with this device that have included lack of access to the infant, inflexibility of the neck seal, and thermoregulatory problems. A new device developed over the last 3 years by Drs Southhall and Samuels of the Brompton Hospital and Horner and Wells Company of London, England, is said to have corrected the problems of the previous Air Shields model. We recently acquired the infant version of the Horner and Wells' negative-pressure ventilator for evaluation and use in the sick newborn population at our hospital. **Materials & Methods**: The device tested consists of: (1) a custom built isolette (35 x 15 x 16 inches), (2) a negative-pressure suction unit, (3) a negative-pressure monitor, (4) a latex neck seal and protector. The Puritan-Bennett #0612 test lung (Puritan-Bennett Corp, Carlsbad CA) was utilized to determine: (1) the range of negative pressures generated by the device, measured in the negative-pressure chamber circuit and in both continuous and intermittent negative-pressure modes; (2) the ability of the device to inflate test lungs as compared to a positive-pressure ventilator; and (3) the intrinsic leak during operation. The unit was tested by monitoring volume changes while holding the flowrates, inspiratory time, and respiratory rate constant and adjusting peak inspiratory pressure from 20 to 40 cm H_2O. Datapoints were obtained, repeated in triplicate, and averaged. **Results**: The operating limits of this negative-pressure device were found to be pressure -3 to -40 cm H_2O, respiratory rate 1 to 60/min, and inspiratory time 0.5 to 20 s. The device generated 40-70% of the volume generated by the Sechrist Infant Ventilator (Sechrist Industries Inc, Anaheim CA) at comparable positive-pressure settings. Testing the device for air leaks during operation, by placing feathers at four quadrants in the negative-pressure chamber during operation over a range of intermittent and continuous negative pressures, resulted in no visible feather movement (ie, no air leak) over all ranges tested. **Conclusions**: The use of negative-pressure devices is not new in the treatment of

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neonates with respiratory disorders. However, the uses, physiologic effects, and safety have not been satisfactorily tested or established. With the recent interest in the use of these devices for neonates, we think that well-designed laboratory and clinical studies should be performed. We intend to study populations that will include infants in severe respiratory failure (extracorporeal membrane oxygenation [ECMO] candidates), ventilator-dependent infants with severe bronchopulmonary dysplasia (BPD), and very-low-birthweight (VLBW) infants requiring prolonged positive pressure ventilation. (OF-90-150)

The Relief of Upper-Airway Obstruction in a Child with Osteogenesis Imperfecta: Case Summary—Shari A vanBeuzekom RRT. Primary Children's Medical Center, *Salt Lake City, Utah.*

I report on the use of mask CPAP to relieve an upper-airway obstruction prior to performing a tonsillectomy and adenoidectomy (T & A) procedure on a child with osteogenesis imperfecta. **Case Summary:** A 6-year-old Latin American boy with osteogenesis imperfecta presented with a history of recurrent pneumonias 1 to 2 times/year and long-standing nighttime snoring. He was observed in the hospital, while being treated for respiratory syncytial virus (RSV), to be suffering from sleep-related hypoventilation. ENT consultation was requested and evaluation revealed tonsillar and adenoidal hypertrophy. Due to RSV, atelectasis, and supplemental oxygen needs, the T & A procedure could not be performed during this admission. Mask CPAP was administered for 2 nights and evaluated for feasibility. On mask CPAP of 6 cm H_2O, transcutaneous CO_2 tension (P_{tcCO_2}) was maintained at 43-45 torr and pulse oximeter O_2 saturation (S_{pO_2}) ranged from 93-96% on 1 L/min of supplemental O_2. The level of CPAP support was gradually increased to 10 cm H_2O because of increasing P_{tcCO_2} and snoring. The following night the patient was placed on 10 cm H_2O of CPAP, required no supplemental O_2, and rested comfortably throughout the night; morning arterial blood gas values were within normal limits. The patient tolerated mask CPAP, and a chest radiograph showed improved aeration of the lungs. The parents were instructed in the use of mask CPAP, home equipment was arranged for, and the patient was discharged to home. **Conclusion**: Through the use of mask CPAP, this patient's medical status was effectively stabilized, and he could be discharged from the hospital to recover from his respiratory illness in the less expensive environment of his home, while awaiting approval for the T & A procedure. (OF-90-159)

Positive Pressure vs Negative Pressure in the Treatment of Nocturnal Sleep Hypoventilation in Children with Congenital Muscular Dystrophy: Two Cases—Shari A vanBeuzekom RRT. Primary Children's Medical Center, *Salt Lake City, Utah.*

Two brothers with congenital muscular dystrophy were treated with mask continuous positive airway pressure (CPAP), mask BiPAP "S" (a combination of CPAP and pressure support), and cuirass negative-pressure ventilation for sleep-related hypoventilation and CO_2 retention. **Case Summary 1**: A 5-year-old white boy, presenting with general muscle weakness, chronic morning headaches, irritability, and general malaise underwent a sleep study that verified suspected hypercarbia, decreased pulse-oximeter O_2 saturation (S_{pO_2}), and significant sleep-related hypoventilation. Mask CPAP was then administered to the subject for 2 nights. A sleep study, with the subject on mask CPAP, revealed that transcutaneous CO_2 tension (P_{tcCO_2}) increased and S_{pO_2} decreased. The subject was then fitted for a cuirass negative-pressure ventilator. Two consecutive sleep studies, with the subject receiving negative-pressure ventilation, revealed that P_{tcCO_2} and S_{pO_2} remained stable. **Case Summary 2**: An 8-year-old white boy, presenting with general muscle weakness, lethargy, and moderate scoliosis, underwent a sleep study, which verified increased P_{tcCO_2} and decreased S_{pO_2}. Mask BiPAP "S" was then administered to the subject for 3 nights. A sleep study, with the patient on mask BiPAP "S," revealed that P_{tcCO_2} increased, S_{pO_2} decreased, and episodes of alveolar hypoventilation occurred. The subject was then fitted for a cuirass negative-pressure ventilator. Three consecutive sleep studies, with the subject receiving negative-pressure ventilation, revealed that P_{tcCO_2} and S_{pO_2} remained stable. **Conclusion**: The findings of these two patient trials suggest that sleep-related hypoventilation, associated with congenital muscular dystrophy, can be successfully managed noninvasively with cuirass negative-pressure ventilation. (OF-90-160)

Rescue Treatment of Two Patients with Pulmonary Hypoplasia by the Infrasonics High-Frequency Flow Interrupter (HFFI)—Kelvin MacDonald RCP, David Wirtschafter MD, Ralph E Franceschini MD, Elizabeth Salaz RRT. Kaiser Permanente Medical Center, *Los Angeles, California.*

Premature rupture of fetal membranes (PROM) > 5 days in infants ≤ 34 weeks is associated with a high incidence of pulmonary hypoplasia requiring vigorous ventilatory assistance. Rescue with the Infrasonics high-frequency flow interrupter (HFFI) was initiated in two of our patients who were refractory to aggressive conventional ventilatory (CV) and pharmacologic support. Pulmonary mechanics were measured prior to HFFI with the Med-Science RDS4500 system (Med-Science, St Louis MO). **Case Summary 1**: This patient was a 1440-g 28-wk-old (gestational age) girl born by Caesarean section, PROM 13 days. At 8 hours (postnatal age) on CV support at IMV 100/min, PIP 44 cm H_2O, PEEP 5 cm H_2O, T_I 0.3 s, F_{IO_2} 1.0, and $\bar{P}_{aw}$ 20 cm H_2O, the pH was 7.20, P_{aCO_2} 81 torr, P_{aO_2} 20 torr, BE 1, $P_{(A\text{-}a)O_2}$ 593 torr, oxygen index (OI) 100, C_{rs} 0.2 mL/cm H_2O, and R_{aw} 170 cm $H_2O \cdot s \cdot L^{-1}$. The patient was then placed on HFFI at 15 Hz, amplitude 46 cm H_2O, $\bar{P}_{aw}$ 18 cm H_2O, IMV 10/min, PtP 40 cm H_2O, PEEP 17 cm H_2O, and T_I 0.2 s; and 12 hours later the pH was 7.33, P_{aCO_2} 52 torr, P_{aO_2} 41 torr, and BE 1. HFFI was continued for 48 hours and CV support was needed for an additional 11 days. **Case Summary 2**: This patient was a 1890-g 32-wk-old (gestational age) girl born by Caesarean section, PROM 50 days. At 24 hours (postnatal age) on CV support at IMV 110/min, PIP 35 cm

H_2O, PEEP 1 cm H_2O, T_I 0.26 s, F_{IO_2} 1.0, and $\bar{P}_{aw}$ 7.1 cm H_2O, the pH was 7.38, P_{aCO_2} 60 torr, P_{aO_2} 18 torr, BE 9, $P_{(A-a)O_2}$ 620 torr, OI 39.4, C_{rs} 0.2 mL/cm H_2O, and R_{aw} 208 cm $H_2O \cdot s \cdot L^{-1}$. The PEEP was increased to 8 cm H_2O and arterial blood analysis revealed pH 7.53, P_{aCO_2} 71 torr, P_{aO_2} 29 torr. The patient was then placed on HFFI at 15 Hz, amplitude 42 cm H_2O, $\bar{P}_{aw}$ 16 cm H_2O, IMV 4/min, PIP 30 cm H_2O, PEEP 15 cm H_2O, and T_I 0.26 s; and 12 hours later the pH was 7.62, P_{aCO_2} 41 torr, P_{aO_2} 43 torr, and BE 20. HFFI was continued for 50 hours and CV support was needed for an additional 12 days. Neither patient demonstrated right-to-left shunt by echocardiogram or pre-/postductal arterial blood samples. Both patients were eligible for extracorporeal membrane oxygenation (ECMO) by $P_{(A-a)O_2}$ and OI criteria, however both were ineligible because they weighed less than 2.0 kg. Ultimately, both patients were discharged home without additional pulmonary support. **Conclusion**: Our preliminary experience suggests effective ventilation with HFFI-IMV may be useful in patients with pulmonary hypoplasia without air leak, refractory to conventional ventilation. (OF-90-039)

Neonatal and Pediatrics Critical Care

Blow-by Oxygen Delivery Capabilities of the Laerdal Infant Manual Resuscitator—Timothy A Williams RRT. Miami Valley Hospital. *Dayton, Ohio.*

The purpose of this study was to evaluate the effectiveness of the Laerdal Infant Manual Resuscitator as a device suitable for the delivery of blow-by oxygen (some recent infant resuscitation courses have stated that this is impossible and have instructed providers to disassemble bags to provide blow-by O_2). **Method & Materials**: A Laerdal Intubation Mannequin (Laerdal Inc, Armonk NY) was fitted with a polarographic O_2 analyzer sensor (Instrumentation Laboratories, Lexington MA) in the mouth of the mannequin with the sensor tip at the lips. Twenty-five Laerdal Infant Manual Resuscitators complete with tail valve and reservoir bag were fitted with disposable infant resuscitation masks (Vital Signs Inc, Totowa NJ). A single calibrated O_2 flowmeter (Fisher & Porter, Warminster PA) was used to supply 100% O_2 to the bags at 5 L/min. F_{DO_2} was measured at the mannequin's mouth when each bag was at a distance of 0, 1, and 2 inches from the mouth. All F_{DO_2} readings stabilized within 30 seconds. To allow true evaluation of blow-by capability, the bags were not squeezed. **Results**: Mean F_{DO_2} (SD) [range] was 0.89 (0.044) [0.76-0.96] when the bags were 0 inches from the mouth, 0.56 (0.058) [0.40-0.74] when the bags were 1 inch from the mouth, and 0.49 (0.056) [0.26-0.57] when the bags were 2 inches from the mouth. It is suspected that ventilation airflow within the NICU may have contributed to the increase in F_{DO_2} range that was observed as the bags were positioned away from the mannequin's mouth. **Conclusion**: The findings of this study suggest that the Laerdal Infant Manual Resuscitator positioned directly over the face, with reservoir bag and tail valve in place, is suitable for blow-by delivery of O_2 up to 89%. (OF-90-001)

Evaluation of the Sechrist BreathTracker Manometer—Kelvin MacDonald RCP, Dennis L Vinson RCP, Elizabeth Salaz RCP, Donn Webb RCP. Kaiser Permanente Medical Center, *Los Angeles, California.*

Guidelines for neonatal resuscitation have recently been established jointly by the American Heart Association and the American Academy of Pediatrics. The guidelines specify that manual ventilation should be provided at a rate (f) of 40 breaths/min and at a peak inspiratory pressure (PIP) of 20 cm H_2O. We evaluated a new electronic manometer, the BreathTracker (Sechrist Industries, Anaheim CA), for its ability to aid caregivers in following these guidelines. The manometer provides visual display of the f, an audible tone when the PIP limit is reached, and a separate tone when it is exceeded. **Methods**: Six RCPs and four MDs provided bag-mask ventilation to a mannequin using flow-dependent (Dupaco, Oceanside CA) or self-inflating (Laerdal Medical, Armonk NY) resuscitators with feedback provided by the Sechrist electronic manometer or the Dwyer Magnehelic manometer (Dwyer Precision Inc, Jacksonville Beach FL). The participants were told to bag at a f of 40 breaths/min and a PIP of 20 cm H_2O for 3 min. Pressures were recorded by a Pneumogard 1230A (Novametrix, Wallingford CT) and saved for comparison. **Results**:

The Effect of Resuscitator and Manometer on Caregivers' Ability To Ventilate at f of 40 breaths/min and PIP of 20 cm H_2O

Resuscitator/Manometer	f	PIP	Overinflations*
Laerdal/Dwyer	27 (8)	25 (2.5)	5 (2)
Laerdal/Sechrist	36 (3)	19 (2)	0
Dupaco/Dwyer	32 (9)	24 (3)	5 (1)
Dupaco/Sechrist	39 (2)	21 (2)	1 (1)

*Overinflations is the number of breaths delivered at PIP ≥ 25 cm H_2O.

All values in Table are mean (SD) for total participants (6 RCPs and 4 MDs).

Conclusion: Our results demonstrate that the Sechrist BreathTracker improved the ability of the operator to follow the recommended guidelines for f and PIP during manual bag-mask resuscitation, especially when the Dupaco flow-dependent bag was used, which is the standard bag used in our unit. We suggest that this combination of audio and visual feedback during resuscitative efforts may reduce excessive ventilation provided by inexperienced caregivers. (OF-90-051)

The Utility of Flexible Fiberoptic Bronchoscopy in the Diagnosis of Stridor in Infancy—Sandra King RRT, George B Mallory Jr MD. Arkansas Children's Hospital, *Little Rock, Arkansas.*

Although stridor in infancy is commonly diagnosed by clinical assessment, further evaluation is required for a precise anatomic diagnosis to be made. Airway fluoroscopy (AF) has become accepted as a definitive method of evaluating these infants. In this study we evaluated flexible fiberoptic bronchoscopy (FFB) as a means to detect structural defects of the upper and

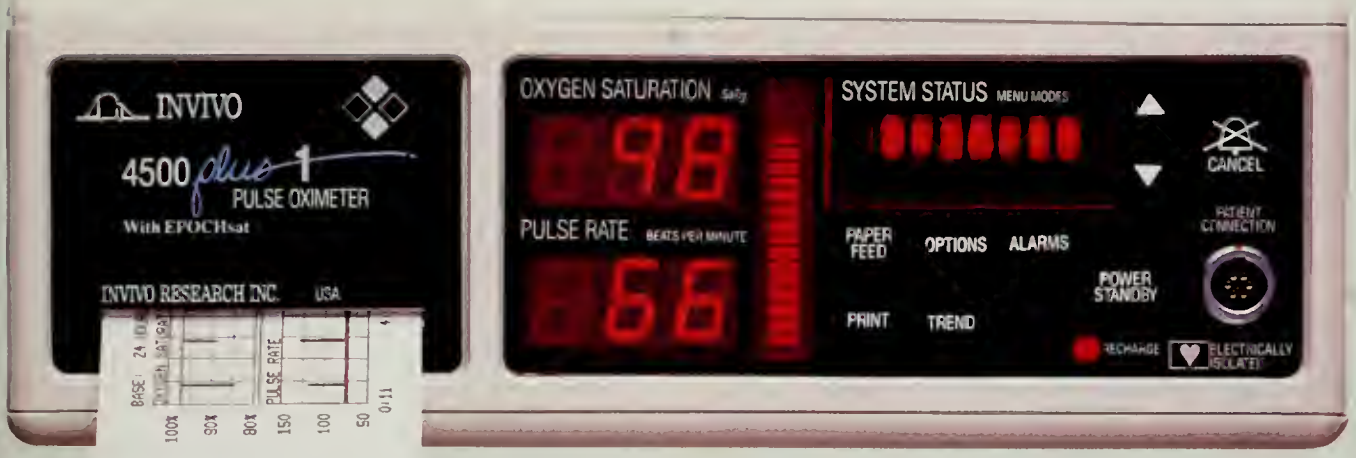
lower airway in infants with clinically diagnosed stridor. **Methods**: Twenty-six infants with stridor were evaluated with either an Olympus BR3C4 or BF3C10 Pediatric Bronchoscope over a 6-year period. Mean age was 4.4 ± 3.18 mo (SD) and mean weight was 5.6 ± 1.95 kg. Mean onset of stridor was at 1.3 ± 1.78 mo. Three patients were born prematurely, 3 with spina bifida, and 20 with no predisposing conditions. Twelve of the 26 infants also received AF. **Results**: Structural abnormalities of the upper airway were detected by FFB in all 26 patients: laryngomalacia (LMC) was detected in 19, vocal cord paralysis (VCP) in 2, subglottic stenosis (SGS) in 1, subglottic hemangioma (SGH) in 2, VCP and SGS in 1, and LMC and SGS in 1. Other structural abnormalities including tracheomalacia, vascular ring, pharyngeal obstruction, and bronchomalacia were found by FFB in 13 of the 26 patients. All patients received oximetry and ECG monitoring during FFB procedures. Only one patient developed complications during FFB: Marked worsening of airway obstruction associated with transient significant desaturation after sedation was experienced by this patient. In this instance, bag and mask ventilation was provided until naloxone reversed the effects of the previously administered meperidine. Patient outcome was generally good. Tracheostomy was not required by any of the patients. One LMC patient had obstructive sleep apnea and required nocturnal use of supplemental O_2 for 6 mo. One patient died at home of probable aspiration. Although LMC is the most common anatomic abnormality to cause stridor in infancy, other findings with different clinical significance are common. AF was performed on 12 of these patients; in 2 of these patients there was complete agreement between FFB and AF in the diagnosis made, in 2 there was partial agreement, and in 8 there was a lack of agreement (incorrect diagnosis was made by AF). **Conclusions**: Our data shows that FFB (1) appears to be a safe method of evaluating stridor in infants, (2) is more precise than AF in making an anatomical diagnosis, and (3) permits definitive diagnosis of lower airway abnormalities that are commonly present in infants with stridor. A consideration of using FFB for this purpose is the high cost (at our institution the cost of FFB is $778.00 and the cost of AF is $112.00). (OF-90-018)

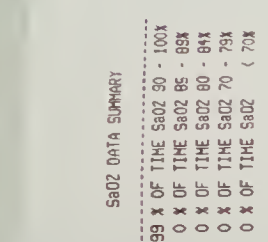
The Use of Extracorporeal Membrane Oxygenation (ECMO) in Severe Pediatric Respiratory Distress Syndrome: Case Summary—Patricia A English MS RRT, Robert M Kacmarek PhD RRT, Daniel P Ryan MD, Daniel P Dudoody MD. Massachusetts General Hospital, *Boston, Massachusetts.*

A 13-month-old girl experienced a severe skin reaction after receiving sulfamethoxazole (Bactrim) therapy for the treatment of otitis media. The child was diagnosed with Stevens-Johnson syndrome and admitted to our Burn Center. On Hospital Day 8, she exhibited signs of respiratory distress, requiring continuous oxygen therapy. She subsequently developed bilateral airspace disease, and was intubated, ventilated, and transported to our PICU. She continued to deteriorate despite vasopressor therapy, paralysis, and maximum conventional ventilation (Control mode, f 48 breaths/min, V_T 100 mL, PIP 80 cm H_2O, F_{IO_2} 1.0, and PEEP 12 cm H_2O). At this time, with continuous $NaHCO_3$ infusion, arterial blood-gas analysis revealed P_{aO_2} 51 torr, P_{aCO_2} 54 torr, and pH 7.36. An open-lung biopsy revealed no inflammatory or infectious agents, and venous-arterial extracorporeal membrane oxygenation (ECMO) was instituted, flows up to 2.4 L were required to maintain oxygenation. After 17 days of ECMO, the patient showed little improvement, and she was placed on the lung transplant list. Thirty-three days into her ECMO course, an ultrasound revealed a small intracranial hemorrhage. She was removed from ECMO and conventionally ventilated (Control mode, f 50 breaths/min, V_T 100 mL, F_{IO_2} 1.0, PIP 48 cm H_2O, and PEEP 10 cm H_2O). Arterial blood-gas analysis revealed P_{aO_2} 63 torr, P_{aCO_2} 52 torr, and pH 7.41. She was maintained on conventional ventilation for 25 more days before showing dramatic improvement in pulmonary function. She was subsequently weaned from mechanical ventilation and discharged on Hospital Day 111. **Conclusion**: Prolonged ECMO appears to be a viable alternative to conventional mechanical ventilation in the treatment of severe refractory respiratory failure, and we suggest that ECMO may have been the key factor, in this case, that allowed time for the child's acute pulmonary process to reverse. (OF-90-156)

Cycling: An Alternative Method for Weaning from Extracorporeal Membrane Oxygenation (ECMO)—Lynne K Bower RRT, Jonathan Cronin MD, Noah D Perlman RRT. The Children's Hospital, *Boston, Massachusetts.*

The most common method of weaning from extracorporeal membrane oxygenation (ECMO) support involves decreasing the amount of blood flow by 4-6 mL · kg^{-1} · min^{-1} as the patient's blood gas values allow. When < 50% bypass is achieved, ventilator support is increased. We have developed the 'cycling' method to determine when a patient is ready to be removed from ECMO, which utilizes minimal ventilator support throughout the entire ECMO run. **Methods**: At our institution, neonatal patients (on ECMO) are routinely maintained on a minimum of 100 mL · kg^{-1} · min^{-1} of blood flow with ventilator settings of F_{IO_2} 0.21, PIP/PEEP 20/5 cm H_2O, and f 5 breaths/min. When there is clinical evidence of pulmonary improvement, the ventilator settings are increased to F_{IO_2} 1.0, PIP/PEEP 30/5 cm H_2O, and f 30 breaths/min. The ECMO flow is then decreased to 30 mL · kg^{-1} · min^{-1} and an arterial blood-gas sample is obtained. If the P_{aO_2} is > 100 torr, the patient is cycled off ECMO by clamping the cannulas and allowing the blood to flow via the bridge. The F_{IO_2} is then reduced over a 20-min period; if at F_{IO_2} of 0.30 the P_{aO_2} is > 60 torr, the patient is decannulated. **Results**: Using this method for the past 4 years in 114 neonatal medical patients who have required ECMO (with an average time on ECMO of 144 hours/patient), we have achieved a 95% survival rate. This compares favorably to the National ECMO Registry survival rate of 88% for 2,622 neonatal medical patients who have required ECMO. The incidence of patient and mechanical complications has been 8.2% and 2.4%, respectively, compared to the National Registry rates of 11% and 3.8%. **Conclusions**: Although the cycling method of weaning from ECMO may require slightly





SaO2 DATA SUMMARY

99 % OF TIME	SaO2 90 - 100%
0 % OF TIME	SaO2 85 - 89%
0 % OF TIME	SaO2 80 - 84%
0 % OF TIME	SaO2 70 - 79%
0 % OF TIME	SaO2 < 70%

EPOCHSAT STATISTICS

BAT OF HIGHEST OCCURANCE (NORMAL) = 97 %
DROP: 3% DURATION: 1 MIN 0 SEC BASE: 24 HR
TOTAL EPOCHSAT COUNT - 5
AVERAGE MINIMUM SaO2 DURING ALL EPOCHSAT EVENTS - 89
OF EPOCHSAT EVENTS LESS THAN 90% - 2
AVERAGE DURATION OF EPOCHSAT EVENTS - 2 MIN. 0 SEC.
AVERAGE RECOVERY OF EPOCHSAT EVENTS - 1 MIN 0 SEC

EPOCHSAT EVENT #	LOG TIME	LOWEST SaO2	DURATION(T)	RECOVERY(T)	PR
1	01:01	85%	2 MIN. 0 SEC	1 MIN 0 SEC	120
2	03:01	89%	2 MIN 40 SEC	1 MIN 40 SEC	130
3	04:31	91%	2 MIN 40 SEC	1 MIN. 40 SEC	82
4	11:01	91%	2 MIN. 0 SEC	1 MIN. 0 SEC	82
5	17:01	90%	2 MIN 0 SEC	1 MIN. 0 SEC	100

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more ECMO hours than the more conventional method of weaning—possibly because of less ventilator support during the ECMO run—it is associated with increased survival and decreased complication rates. Use of the cycling method of weaning from ECMO may avoid thromboembolic phenomenon resulting from use of heparin-bonded circuits at low blood-flowrates. (OF-90-083)

Changes in Pediatric Ventilatory Dynamics during Mechanical Ventilation with PSV—Terry L Forrette MHS RRT, Jimmy M Cairo PhD, LSU Medical Center; Darlene D Cimo BS RRT, A Joanne Gates MD, Children's Hospital—*New Orleans, Louisiana.*

Study Question: How does PSV affect spontaneous tidal volume (V_T), spontaneous breathing frequency (f), and spontaneous minute volume ($\dot{V}_E$) during mechanical ventilation? **Method**: We studied 8 pediatric patients, ages 20 months to 11 years (mean [SD] 6.2 [4.1] years), who were mechanically ventilated in the SIMV mode with a Siemens Servo 900C ventilator that was interfaced with a computerized data-collection system. None of the patients had a history of obstructive lung disease or neurologic impairment. Spontaneous V_T (mL/kg body weight), f (breaths/min), and $\dot{V}_E$ (mL/min/kg body weight) were measured at 7 levels of PSV (0, 5, 10, 15, 20, 25, 30 cm H_2O). Data were collected at 1-s intervals over a 5-min period following a 5-min stabilization period at each level of PSV. **Results:** PSV affected spontaneous V_T and f in a linear fashion ($r = 0.992$ and -0.985, respectively; $p < 0.01$). When compared to PSV-0, spontaneous V_T increased significantly from PSV-10 to PSV-30 (range [SEM] = 6.7 [0.817] to 15.2 [1.07], $p < 0.05$) while spontaneous f decreased at PSV-20 to PSV-30 (range [SEM] = 29.8 [3.62] to 23.7 [1.88], $p < 0.05$). ANOVA between PSV levels showed significant increases in spontaneous V_T between PSV-10 to PSV-30 ($p < 0.05$). Significant decreases in spontaneous f occurred between PSV levels below 20 cm H_2O ($p < 0.05$), but no significant changes occurred between PSV-20, PSV-25, or PSV-30 ($p > 0.10$). PSV did not affect spontaneous $\dot{V}_E$ in a linear fashion ($r = 0.471$, $p > 0.10$) and no significant changes were seen between PSV levels ($p > 0.10$). **Conclusions**: Varying the level of PSV affects the depth and/or rate of spontaneous ventilation without changing minute ventilation. PSV levels greater than 20 cm H_2O do not significantly improve the efficiency of ventilation, in relationship to breathing frequency, even though spontaneous V_T continues to increase. These data suggest that for pediatric patients the primary variable to monitor, in terms of ventilatory efficiency, is breathing frequency. (OF-90-043)

Body-Temperature Transcutaneous Sensor Allows Long-Term CO_2 Monitoring in the Neonate—Barbara L Hendon RRT, Neel B Ackerman MD. Presbyterian Hospital of Dallas, *Dallas, Texas.*

Because commercial transcutaneous CO_2 sensors are usually integrated with transcutaneous O_2 sensors, they require heating of the skin beneath the sensor and consequent frequent site changes to minimize the incidence of thermal injury. The purpose of this study was to evaluate the use of a combined transcutaneous O_2-CO_2 sensor maintained at 37 °C for prolonged periods of time. **Method**: One hundred infants, gestational age 26-42 weeks and birthweight 0.62-4.3 kg, were studied. Infants ranged from being in mild respiratory distress requiring only supplemental O_2 to being critically ill requiring high-frequency ventilation or extracorporeal membrane oxygenation. All infants had peripheral or umbilical arterial catheters that had previously been placed for clinical indications and required continuous P_{CO_2} monitoring. A Novametrix Model 840 Monitor with a PN4474 sensor assembly was applied and the sensor heater control was set at 37 °C. After an initial stabilization period, arterial blood gas values and transcutaneous values were obtained every 1 to 3 hours, depending on the clinical status of the infant. **Results**: There was poor correlation between arterial O_2 tension (P_{aO_2}) and transcutaneous O_2 tension (P_{tcO_2}) values. However, there was good correlation between arterial CO_2 tension (P_{aCO_2}) and transcutaneous CO_2 tension (P_{tcCO_2}) values ($p < 0.01$). If the initial two sets of measurements demonstrated a consistency in P_{aCO_2}-P_{tcCO_2} difference, P_{tcCO_2} could subsequently be used (up to 24 hours) to accurately estimate P_{aCO_2} (± 3 to 5 torr). There were no thermal injuries or other complications of the technique. Sensors remained in place an average of 13.7 ± 2.8 hours. **Conclusion**: Although the use of a transcutaneous O_2-CO_2 sensor at body temperature does not allow accurate monitoring of P_{tcO_2}, it does allow accurate monitoring of P_{tcCO_2}, which enables continuous accurate noninvasive estimates of P_{aCO_2} to be made over long periods of time without risk of thermal injury to the skin. (OF-90-049)

An Evaluation of the Accuracy of the Ohmeda Oxicap 4700 in a Neonatal Population—John W Salyer RRT, Marsha Rogers CRTT, Tim Myers RRT, Robert L Chatburn RRT, Rainbow Babies and Childrens Hospital, *Cleveland, Ohio.*

Research Question: In neonates, what is the agreement between end-tidal CO_2 tension (P_{etCO_2}) measured by the Ohmeda Oxicap 4700 monitor and arterial CO_2 tension (P_{aCO_2}), and oxygen saturation (S_{pO_2}) measured by the Oxicap 4700 and arterial oxygen saturation (S_{aO_2})? **Methods**: Inclusion criteria included any intubated neonate who did not have chronic lung disease, and had an indwelling arterial line. A total of 16 patients were included in the study; each patient was studied once. Mean (SD) birthweight was 2,338 (1,263) g, with a range of 713 g to 5,110 g. Eight patients suffered from respiratory distress syndrome; four from meconium aspiration syndrome; and one each from sepsis, necrotizing enterocolitis, persistant pulmonary hypertension of the newborn, and hydrops fetalis. The Oxicap 4700 (Ohmeda, Louisville CO) was operated according to the manufacturer's specifications, and it was calibrated before each application. Patients were placed on the monitor, and a sample of arterial blood was taken within 15 to 30 min, divided into two portions and analyzed by both a Radiometer ABL-4 blood-gas analyzer (Radiometer, Copenhagen) and a Radiometer OSM-3 hemoximeter (Radiometer, Copenhagen). The Oxicap 4700 pulse-oximeter probe was ap-

plied to either the foot or the hand, depending on which application rendered the best plethysmographic signal on the monitor. Differences between mean values were tested with Student's *t* test, and limits of agreement between variables were computed. Significance was established at $p < 0.05$. **Results**: There was no significant difference between mean (SD) S_{pO_2} 94.0 (3.9) % and mean (SD) S_{aO_2} 94.1 (3.7) %, $p = 0.79$. There was, however, a statistically significant difference between mean (SD) P_{etCO_2} 31.3 (9.1) torr and mean (SD) P_{aCO_2} 39.1 (10.1) torr. Limits of agreement were +0.8 torr to +14.8 torr for P_{etCO_2} and P_{aCO_2}, and -3.9% to +3.7% for S_{pO_2} and S_{aO_2}. **Conclusions**: The agreement between S_{pO_2} and S_{aO_2} was excellent and consistent with that reported by others. However, the use of pulse oximetry to prevent hyperoxemia in neonates has yet to be proven efficacious. The agreement between P_{etCO_2} and P_{aCO_2} was clearly poor enough to make estimation of P_{aCO_2} from P_{etCO_2} unacceptable. There may be clinical utility in using Oxicap-4700 P_{etCO_2} measurements to qualitatively assess changes in ventilation, but this remains to be tested. (OF-90-119)

Measuring and Monitoring

Determination of Vital Capacity in Mechanically Ventilated Patients: A Comparison of Techniques—Robert M Kacmarek PhD RRT, Penny Cheever RRT, Kevin Foley RRT, David Romagnoli MS RRT. Massachusetts General Hospital, *Boston, Massachusetts.*

Vital capacity (VC) has commonly been used as an indicator of ventilatory reserve in mechanically ventilated patients. However, because patient cooperation is required for a valid measurement, reliability of VC is often questioned. We randomly compared two VC-measurement techniques: (1) VC is measured immediately following maximal inspiratory pressure (MIP) determination and (2) VC is measured independent of MIP determination. **Methods**: For both techniques, a Wright respirometer was used to measure VC. In Technique 1, both inspiratory and expiratory VC was measured during the first breath after a 20-second MIP determination, using a one-way valve (Respir Care 1989;34:868). Three measurements were made using Technique 2; the largest was recorded. Each set of measurements was performed at least 1 hour apart. **Results**: Data were obtained on 63 patients (28 women and 35 men, mean [SD] age 65 [16] y). Of these 63 patients, 45 (Group A) were able to cooperate with Technique 2, and 18 patient (Group B) were not. In Group A there were no significant differences between mean [SD] VC measured by Technique 2 (860 [531] mL) and VC measured by Technique 1—either inspiratory (789 [453] mL) or expiratory (894 [519] mL). However, in Group B, there was a significant difference ($p < 0.05$, paired *t* test) between mean [SD] VC measured by Technique 2 (449 [307] mL) and expiratory VC measured by Technique 1 (663 [481] mL). In addition, for the total group (minus those with COPD [n = 37]), there was a moderate correlation (0.54, $p < 0.001$) between expiratory VC (measured by Technique 1) and MIP, with VC predicted from MIP by the following equation: VC = (MIP) (22.8) - 0.795. **Conclusion**: In uncooperative patients, an expiratory VC is measurable after an MIP determination; in cooperative patients, the expiratory VC following MIP determination is equivalent to VC measured by standard technique and can be predicted from MIP in non-COPD patients. (OF-90-142)

The Comparative Work of Spontaneous Breathing When Using One-Way Breathing Valves, Ventilators, or T-Tube for Weaning Studies—George H Hicks MS RRT. Mt Hood Community College, *Gresham, Oregon.*

Various methods have been recommended to measure spontaneous breathing variables. In some a disposable one-way breathing valve is used, while in others the ventilator in CPAP mode (0 cm H_2O) is used. **Study Question**: What method results in the lowest inspiratory work of breathing (WOB_I) when compared to a T-tube? **Methods**: Five measurements of inspiratory pressure (P_{Imax}) and WOB_I (determined by the pressure-volume-loop method) were recorded at the airway of a test lung during simulated breathing (mean [SD] $V_T = 0.5$ [0.01] L; and $\dot{V}_I = 30$, 45, and 60 [2] L/min) while using: T-tube at 40 L/min; 4050 Airlife (Baxter Pharmaseal Div, Valencia CA) and 3500 DHD disposable one-way valves (DHD Medical Products, Canastota NY); and BEAR 2 (Bear Medical, Riverside CA), Puritan-Bennett 7200a (Puritan-Bennett Corp, Overland Park KS) (in the CPAP mode [0 cm H_2O] or in the flow-by mode [base flow = 10 L/min and sensing flow = 3 L/min]), and Servo 900C ventilators. The test lung model, previously described (Chest 1985;88:519), was driven by an Emerson ventilator while attached to the T-tube, valve, or ventilator (sensitivity = -1 cm H_2O). **Results**:

P_{Imax} and WOB_I* during Breathing through T-Piece, Valves, and Ventilators

	$\dot{V}_I$ 30 L/min	45 L/min	60 L/min
	P_{Imax}	P_{Imax}	P_{Imax}
Devices	WOB_I	WOB_I	WOB_I
T-Tube	-0.3 (0.1)	-0.8 (0.1)	-1.2 (0.1)
	0.020 (0.002)	0.022 (0.002)	0.046 (0.006)
4050 Airlife Valve	-3.2 (0.2)	-4.3 (0.2)	-5.8 (0.2)
	0.123 (0.008)	0.172 (0.009)	0.229 (0.006)
3500 DHD Valve	-1.9 (0.1)	-3.1 (0.1)	-3.9 (0.2)
	0.084 (0.008)	0.127 (0.004)	0.160 (0.012)
BEAR 2 Ventilator	-4.0 (0.2)	-5.2 (0.2)	-6.8 (0.2)
	.065 (0.003)	0.072 (0.006)	0.110 (0.007)
Servo 900C Ventilator	-2.8 (0.1)	-3.0 (0.2	-5.8 (0.3)
	0.015 (0.004)	0.013 (0.003)	0.040 (0.006)
PB 7200a Ventilator (CPAP)	-3.2 (0.2)	-3.8 (0.2	-5.7 (0.3)
	0.043 (0.008)	0.053 (0.004)	0.106 (0.009)
PB 7200a Ventilator (flow-by)	-0.2 (0.1)	-2.2 (0.2)	-13.3 (0.3)
	0.011 (0.004)	0.018 (0.006)	0.049 (0.005)

*All P_{Imax} and WOB_I values are shown as mean (SD); P_{Imax} is in cm H_2O, WOB_I is in J.

The one-way valves and the Puritan-Bennett 7200 (CPAP mode) and BEAR 2 ventilators imposed significantly greater WOB_I than did the T-tube ($p < 0.001$, ANOVA and Student's *t* test) , while the Puritan-Bennett 7200 (flow-by mode) and Servo 900C ventilators imposed less WOB_I than did the T-tube. The one-way valves imposed significantly greater WOB_I than did the ventilators ($p < 0.05$, ANOVA and Student's *t* test). **Conclusions:** Using the disposable valves tested increases the WOB_I and may possibly alter breathing pattern during spontaneous breathing trials. Clinical studies are needed to confirm the importance of these findings. (OF-90-133)

The Added Work of Breathing through One-Way Breathing Valves Commonly Used in Weaning Studies—George H Hicks MS RRT. Mt Hood Community College, *Gresham, Oregon.*

A variety of one-way valves are available for measuring spontaneous breathing variables (f, V_T, and $\dot{V}_E$) to determine if a patient is weanable, but the amount of added work imposed by these valves and the influence that they may have on a patient's breathing pattern is not well known. **Study Question:** What is the maximum negative inspiratory pressure (P_{Imax}) and inspiratory work of breathing (WOB_I) required during spontaneous breathing through various valves and through a T-tube at different inspiratory flowrates? **Methods:** Five measurements of P_{Imax} and WOB_I (determined by the pressure-volume-loop method) were recorded at the airway of a test lung during simulated spontaneous breathing (mean [SD] V_T = 0.5 [0.01] L; and $\dot{V}_I$ = 30, 45, and 60 [2] L/min) through two samples of a T-tube at 40 L/min, 1400 Rudolph valve (Hans Rudolph, Kansas City MO), 4050 Airlife valve (Baxter Pharmaseal Div, Valencia CA), 3500 DHD valve (DHD Medical Products, Canastota NY), and 117c Instrumentation Industries valve (Instrumentation Industries, Bethel Park PA). The test lung model, previously described (Chest 1985;88:519), was employed. Gas was supplied to the inspiratory side of each valve from a T-tube running at 40 L/min, while the test lung was driven by an Emerson ventilator (J H Emerson Co, Cambridge MA). **Results:**

P_{Imax} and WOB_I during Breathing through a T-Tube and One-Way Valves*

	$\dot{V}_I$		
	30 L/min	45 L/min	60 L/min
Devices	P_{Imax} / WOB_I	P_{Imax} / WOB_I	P_{Imax} / WOB_I
T-Tube	-0.3 (0.1)	-0.8 (0.1)	-1.2 (0.1)
	0.020 (0.002)	0.022 (0.002)	0.046 (0.006)
1400 Rudolph Valve	-1.3 (0.1)	-1.5 (0.1)	-2.2 (0.2)
	0.050 (0.006)	0.069 (0.007)	0.100 (0.009)
4050 Airlife Valve	-3.2 (0.2)	-4.3 (0.2)	-5.8 (0.2)
	0.123 (0.008)	0.172 (0.009)	0.229 (0.006)
3500 DHD Valve	-1.9 (0.1)	-3.1 (0.1)	-3.9 (0.2)
	0.084 (0.008)	0.127 (0.004)	0.160 (0.012)
117c II Valve	-5.9 (0.2)	-6.6 (0.2)	-7.2 (0.3)
	0.237 (0.004)	0.278 (0.011)	0.308 (0.025)

*All P_{Imax} and WOB_I values are shown as mean (SD); P_{Imax} is in cm H_2O, WOB_I is in J.

All four valves resulted in significantly greater ($p < 0.001$,ANOVA and Student's *t* test) P_{Imax} and WOB_I with increasing $\dot{V}_I$ and compared to the T-tube at each $\dot{V}_I$. **Conclusions:** The four valves tested imposed more than twice (eg, Rudolph valve) to ten times (eg, Instrumentation Industries valve) the WOB_I imposed by a T-tube. This added work may affect the patient's breathing pattern and may distort spontaneous breathing variables. Clinical studies are needed to confirm the importance of these findings. (OF-90-134)

The Effect of 5% Dextrose Infusion on the Carbohydrate:Fat Proportions of Feeding Regimens in ICU Patients—Marcia Kemper BA CRTT, Xiaolu Sun MD, Charles Weissman MD, Allen I Hyman MD. Columbia University, College of Physicians & Surgeons, *New York, New York.*

Studies have indicated that feeding regimens high in lipids (ie, consisting of approximately 50% lipids) are better tolerated by the respiratory and metabolic systems than regimens made up primarily of carbohydrates. We studied the nutritional composition of routine clinical feeding regimens and the metabolic rate of critically ill ventilator-dependent postoperative patients receiving these regimens to determine the actual composition provided and to assess the adequacy of energy-need coverage. **Methods & Materials:** The lipid, amino acid, and carbohydrate content of enteral and/or parenteral feedings to 17 patients were analyzed in 144 studies. The calories from daily infusions of 5% dextrose (D5) in intravenous solution were also included in the analysis. Metabolic rate was measured and compared to calories provided by the nutritional regimens and D5 solutions. Metabolic measurements were performed using either the SensorMedics Deltratrac (SensorMedics, Yorba Linda CA) interfaced to the BEAR 1 or BEAR 2 ventilator (Bear Medical, Riverside CA) with a Puritan-Bennett AO-1 blender (Puritan-Bennett, Carlsbad CA) in-line, or the Engstrom metabolic computer interfaced to the Erica ventilator (Gambro-Engstrom, Virgina Beach VA). All equipment was interfaced according to manufacturer specifications and calibrated before use. **Results:** The mean (SD) resting metabolic rate was 1,709 (327) kcal/day. The patients received a mean (SD) of 1,821 (600) kcal/day; 108 (0.32) % of their resting nutritional needs were met. A mean (SD) of 847.8 (357) kcal/day was from carbohydrates, 703 (407) from lipids, 263 (127) from amino acids, and 140 (127) from D5 solutions. Carbohydrates contributed a mean (SD) of 50 (19) % of the total calories, lipids 36 (15) %, amino acids 14 (4.7) %, and D5 solutions 11.6 (18.5) %. The mean (SD) percentage of nonprotein calories contributed by fat was 44.5 (17.7). **Discussion:** Although patients on average had 108% of their resting energy expenditure needs met, activity and day-to-day variability of metabolic rate was not covered (Chest 1986;89:254-259). Also, even though the patients were fed the recommended increased amount of lipid, infusions of D5 increased the amount of carbohydrate and thus altered the carbohydrate:fat proportion. **Conclusion:** The contribution of D5 infusions to total caloric intake must be taken into consideration when analyzing carbohydrate intake. (OF-90-057)

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The Effect of Clinical Feeding Regimens on Respiratory Parameters—Marcia Kemper BA CRTT, Xiaolu Sun MD, Charles Weissman MD, Allen I Hyman MD. Columbia University, College of Physicians & Surgeons, *New York, New York.*

It is difficult to determine whether nutrient mixes fed to critically ill ventilator-dependent patients affect respiratory parameters. We sought to determine whether nutrient intake from feeding regimens and 5% dextrose infusion (D5W) had any effect on the respiratory rate (f), respiratory quotient (RQ), and minute volume ($\dot{V}_E$) of mechanically ventilated ICU patients. **Methods & Materials:** We studied 34 critically ill ventilator-dependent postoperative ICU patients. The patients in Group A (n = 17) were being fed via enteral and/or parenteral routes, for a total of 144 study days; and the patients in Group B (n = 23) were receiving only D5W, for a total of 41 study days. Data obtained when six of the patients in Group A were receiving only D5W are included with Group B data. Oxygen consumption ($\dot{V}_{O_2}$), carbon dioxide production ($\dot{V}_{CO_2}$), resting energy expenditure (REE), RQ, and $\dot{V}_E$ were measured using either the SensorMedics Deltatrac (SensorMedics, Yorba Linda CA) interfaced to the BEAR 1 or BEAR 2 ventilator (Bear Medical, Riverside CA) with a Puritan-Bennett AO-1 Blender (Puritan-Bennett, Carlsbad CA) in-line, or the Engstrom metabolic computer interfaced to the Erica ventilator (Gambro-Engstrom, Virginia Beach VA). All equipment was interfaced according to manufacturer specifications and calibrated before use. RQ was calculated as $\dot{V}_{CO_2}/\dot{V}_{O_2}$. The infused calories were analyzed for total caloric intake and carbohydrate content. The reported f is the machine rate and spontaneous rate totalled. All reported measurements were obtained while the patients were in the resting state (Chest 1984;86:815-818). **Results:** The mean (SD) f, RQ, and $\dot{V}_E$ of Group A were 19.2 (5.40) breaths/min, 0.91 (0.08), and 10.25 L/min respectively. The mean (SD) f, RQ, and $\dot{V}_E$ of Group B were 13.2 (2) breaths/min, 0.84 (0.05), and 9.1 (1.8) L/min, respectively. Significant intergroup differences existed for f ($p < 0.001$), RQ ($p < 0.001$), and $\dot{V}_E$ ($p < 0.001$). Group A received a mean (SD) total of 1,821 (600) kcal/day, of which 847 (357) kcal were from carbohydrates, resulting in 50 (19) % of the total calories from carbohydrates. The mean (SD) REE was 1,709 (327) kcal/day. Group B received a mean (SD) total of 309 (174) kcal/day of carbohydrates. When the f was ≤ 20 breaths/min, the RQ was < 1.0; when the f was > 25 breaths/min, the RQ was ≥ 0.85. **Conclusions:** The significant differences between the two groups for all three parameters shows a possible clinical effect of increased nutrient intake. The nutritional regimen may be an etiologic factor of resting tachypnea in ventilator patients. (OF-90-058)

Trancutaneous P_{CO_2} vs End Tidal P_{CO_2} in Ventilated Adults—Tim Blanchette MS RRT, Kathryn Harris BS RRT, John Dziodzio BA. Maine Medical Center, *Portland, Maine.*

Introduction: Continuous noninvasive CO_2 monitoring can provide valuable information in the management of the ventilated adult patient. In this study, we sought to evaluate the acuracy of transcutaneous CO_2 tension (P_{tcCO_2}) and end-tidal CO_2 tension (P_{etCO_2}) measurements compared to arterial CO_2 tension (P_{aCO_2}) measurements in ventilated adult patients. **Methods:** Twenty-one patients (29-82 y), being ventilated for non-anesthesia-related reasons, were included in the study. Mean weight was 81.4 kg (range 50-139 kg). A combination P_{tcO_2}/P_{tcCO_2} sensor of the SensorMedics Transcend monitor (SensorMedics Corp, Anaheim CA) was placed on the upper chest of each patient and maintained at a temperature of 44 °C. The monitor was re-membraned and calibrated twice at the beginning of each day of monitoring. After application, the sensor was left in place for up to 5 hours; no erythema or burns were noted. A Novametrix 7000 combination mainstream P_{etCO_2} monitor/pulse oximeter (Novametrix Medical Systems Inc, Wallingford CT) was attached to the artificial airway per manufacturer's recommendations. Arterial blood gases were obtained per protocol after assuring a 20-minute warm-up time for both instruments. **Results:** Thirty-one blood samples were obtained from the 21 patients (1-3 samples/patient) and P_{aCO_2} was compared to P_{etCO_2} and P_{tcCO_2}. The least-square linear regression of P_{etCO_2} on P_{aCO_2} in the 31 samples yielded a correlation coefficient (r) of 0.73, regression coefficient (slope) of 0.74, and a mean deviation (bias) of -8.35. There was a better linear correlation between P_{tcCO_2} and P_{aCO_2} ($r = 0.88$, slope = 0.98), as well as an improved bias of only 0.4. **Discussion:** P_{tcCO_2} monitors are more labor-intensive than P_{etCO_2} monitors because of the required membrane and site changes. They also respond slower and may produce values significantly different from P_{aCO_2}. Despite these disadvantages, when compared to mainstream P_{etCO_2} measurements, our P_{tcCO_2} values more accurately depicted P_{aCO_2} in our ventilated intensive care patients. CO_2 monitoring is most often requested in patients with abnormal pulmonary physiology such as increased dead space and ventilation-perfusion inequities. These pulmonary pathologies are often present in ICU patients and disturb the correlation between P_{etCO_2} and P_{aCO_2}. **Conclusion:** The findings of our study suggest that in mechanically ventilated ICU adult patients, P_{tcCO_2} monitoring accurately describes P_{aCO_2} and provides a better indication of ventilation status than does P_{etCO_2}. (OF-90-097)

Pulse Oximetry Monitoring in Young Women Receiving Versed and Alfenta—Tim Blanchette MS RRT, Kathryn Harris BS RRT. Maine Medical Center, *Portland, Maine.*

Introduction: Versed (midazolam hydrochloride [Roche]) is a potent sedative agent that has been widely used for conscious sedation. Alfenta (alfentanil hydrochloride [Janssen]) is an opiate analgesic with rapid onset. Both of these medications, alone or in conjunction, may lead to respiratory depression or arrest and thus manufacturers recommend continuous monitoring of respiratory and cardiac function when they are administered. Our study was designed to determine whether clinically important oxygen desaturation occurs following the adminstration of Versed (alone) or Versed and Alfenta (in combination). **Methods:** Thirty-five young women (mean [range] age 22 [13

to 39] y, mean [range] weight 64.5 [46.5 to 107.7] kg), undergoing first-trimester abortions and requiring sedation and/or analgesia, were studied. In an unblinded fashion, an oximeter finger probe was securely placed on the patient's finger prior to the administration of Versed or Alfenta. All patients received Versed in doses ranging from 1 mg to 4 mg (mean 1.8 mg), and 27 patients received Alfenta in doses of 100 µg to 1000 µg (mean 528 µg). Using a Criticare 504-US pulse oximeter (Criticare Systems Inc, Milwaukee WI), oxygen saturation (S_{pO_2}) was recorded every 2 s. S_{pO_2} was measured for 30-90 min after the final sedative or analgesic dose. **Results**: No major desaturation events ($S_{pO_2} < 85\%$ for more than 30 s) occurred in the study group. One patient had 1 minor desaturation episode ($85\% < S_{pO_2} < 90\%$ for over 30 s) and 2 other patients had interesting episodes ($S_{pO_2} < 95\%$ for more than 30 s or $S_{pO_2} < 90\%$ for under 30 s). In 32 of the patients (91%), S_{pO_2} was never < 95% for more than 30 s; and in 34 of the patients (97%), S_{pO_2} was never below 90% for over 30 seconds. **Summary Conclusions**: Versed and Alfenta in the dosages we used were not associated with any major desaturation episodes in the young healthy population studied. Twenty-six (74%) of the patients studied were current smokers with potentially increased HbCO levels, and thus true S_{aO_2} may have been less than measured S_{pO_2}. Because this study was not blinded and patients may have been asked to deep breathe as S_{pO_2} values fell, major desaturations may have been avoided. Our findings suggest that clinically important oxygen desaturation is unlikely in healthy, young women after the administration of low-to-moderate doses of Versed and Alfenta. Further studies are required to confirm these results. (OF-90-098)

Use of Synchronous Independent Lung Ventilation with Unilateral Pulmonary Artery Occlusion in a Patient with Bronchocutaneous Fistula To Estimate the Response to Surgical Pneumonectomy: Case Report—Jonathan Gottlieb MD, Stephen J Connell BA RRT, Dena Vallieu CRTT. Thomas Jefferson University Hospital, *Philadelphia, Pennsylvania.*

Synchronous independent lung ventilation (SILV) has previously been reported as a treatment modality for unilateral lung diseases. We performed SILV in a 76-year-old patient with a large bronchocutaneous fistula from a prior infection with *Mycobacterium tuberculosis*, who required mechanical ventilation with large tidal volumes in order to sustain adequate CO_2 removal. Following admission to the ICU for hypoxemic respiratory failure with metabolic and respiratory acidosis, the patient was intubated and the fistula was packed with an occlusive dressing. Despite careful management, the fistula continued to leak > 500 mL/breath, precluding standard preoperative evaluation with quantitative lung scanning. To estimate what might be the response to surgical pneumonectomy, we simulated pneumonectomy with SILV and selective unilateral pulmonary artery occlusion. SILV was performed using a double-lumen endotracheal tube attached to two Servo 900C ventilators using a synchronization cable. Under fluoroscopic guidance, a 20-mm pressure catheter with an occlusive balloon was inserted via the femoral vein (PA systolic pressure 64 torr, PA diastolic pressure 29 torr). Upon unilateral ventilation of the right (unaffected) lung, S_{aO_2} rose from 96 to 99%, P_{aO_2} rose from 87 to 99 torr, and P_{aCO_2} remained constant. Upon inflation of the balloon, S_{aO_2} fell to 85% and blood pressure decreased to less than 90 systolic, likely from an inability of the right heart to overcome the added pulmonary vascular resistance. Based on these results, we concluded that the patient would probably not tolerate pneumonectomy. **Conclusion**: In selected cases, in which pulmonary function testing, exercise testing, or quantitative lung scan are not possible, use of SILV with unilateral pulmonary artery occlusion to simulate pneumonectomy may be a useful means to evaluate the feasibility of surgical pneumonectomy and may prevent unnecessary costly and potentially fatal results. (OF-90-016)

Determination of Venous Admixture by a Simplified Equation—John M Graybeal CRTT, Garfield B Russell MD. The Pennsylvania State University, *Hershey, Pennsylvania.*

Introduction: Measurement of venous admixture ($\dot{Q}_s/\dot{Q}_t = [C_{cO_2} - C_{aO_2}]/[C_{cO_2} - C\bar{v}_{O_2}]$) is used to monitor progression of pulmonary pathology and response to therapy. The cost, complexity, and delay involved in determining $\dot{Q}_s/\dot{Q}_t$ by conventional methods makes it less than ideal as a frequent monitor of patient progress. To test a simplified method for measuring $\dot{Q}_s/\dot{Q}_t$ we assumed that in the classic equation (1) dissolved oxygen contributes minimally, (2) hemoglobin concentrations of the venous and arterial blood are equivalent, and (3) blood exits the alveolar capillaries fully oxygenated. These assumptions allow the classic equation to be simplified to $\dot{Q}_s/\dot{Q}_{tsim} = (100 - S_{aO_2})/(100 - S\bar{v}_{O_2})$. **Methods**: Following approval by the Animal Utilization Committee, 9 mongrel dogs were anesthetized, paralyzed, and mechanically ventilated with room air. Each dog was monitored by both a femoral and pulmonary artery catheter, a three-lead ECG, and a Perkin-Elmer MGA 1100 mass spectrometer. Simultaneous arterial and mixed-venous blood samples were obtained at random intervals and analyzed by a Corning 168 pH/Blood Gas Analyzer and a Radiometer OSM2 Hemoximeter. Cardiac output was determined by thermodilution technique each time blood was sampled. $\dot{Q}_s/\dot{Q}_t$ and $\dot{Q}_s/\dot{Q}_{tsim}$ were calculated from the blood gas results. Alterations in venous admixture were induced by venous air embolism or prolonged breath-holding. Data were analyzed using linear regression analysis. A p value < 0.05 was considered significant. The bias and standard deviation of the differences were calculated. Improvement or deterioration in $\dot{Q}_s/\dot{Q}_t$ during experimental intervention was also compared with the two techniques. **Results**: 102 sets of measurements were made. $\dot{Q}_s/\dot{Q}_t$ ranged from 6.9% to 89.6% (mean [SD] = 26.1 [17.3] %). Cardiac output ranged from 0.9 to 10.0 L/min. S_{aO_2} and $S\bar{v}_{O_2}$ ranged from 98.0% to 18.4% and 90.7% to 13.7%, respectively. There was a highly significant correlation ($p < 0.001$) between the $\dot{Q}_s/\dot{Q}_t$ and the $\dot{Q}_s/\dot{Q}_{tsim}$ equation results ($r = 0.994$, slope = 0.94, y-intercept = 3.2). The bias and standard deviation of the differences for $\dot{Q}_s/\dot{Q}_{tsim}$ were -1.7% and ± 2.0%, respectively. In the progressive measurements of $\dot{Q}_s/\dot{Q}_t$, the $\dot{Q}_s/\dot{Q}_{tsim}$ correctly predicted 97% of the changes in direction. **Conclusions**: Our

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data show that, in this canine model, $\dot{Q}_t/\dot{Q}_{tsim}$ is an accurate and reliable replacement for the classic venous admixture determination. Although the correlation studies remain to be done in humans, this simplified equation may provide an alternative method for rapid and easy determination of venous admixture in the critical care setting. (OF-90-103)

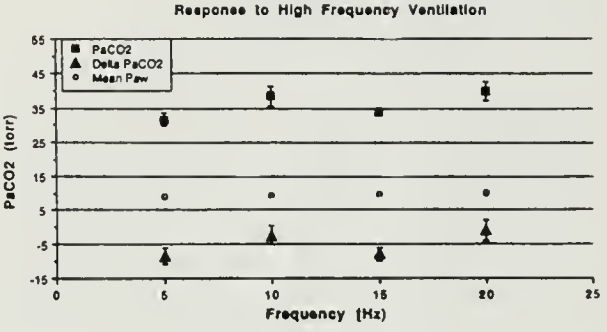
Evaluation of a Portable Carbon Monoxide Monitor To Determine Blood Carboxyhemoglobin Levels in Patients—Carl D Mottram RRT RPFT, Kenneth C Beck PhD, Paul D Scanlon MD, Mayo Clinic, *Rochester, Minnesota.*

Portable carbon monoxide (CO) monitors are used for noninvasive evaluation of smoking habit or smoke inhalation. Manufacturers supply a conversion factor to convert alveolar CO (in parts per million [ppm]) to blood carboxyhemoglobin (HbCO). However, this conversion factor was determined in normal subjects using a 20-second breath-hold (Thorax 1986;41:886-887). We wanted to establish a procedure to estimate HbCO in patients having a pulmonary function test (PFT), using a shorter, more conventional 10-second breath-hold. **Methods**: 32 patients (mean age 58 y, range 38-74 y) referred for arterial blood gas analysis and complete pulmonary function testing participated in the study. Pulmonary function data ranged from normal (TLC > 80% of predicted, FEV_1 > 80% of predicted) to varying degrees of obstruction (FEV_1 as low as 31% of predicted) or mild restriction (TLC as low as 74% of predicted), with D_{LCO} ranging from 33% to 120% of predicted. A Vitalograph-EC50 CO monitor (Vitalograph Medical Instrumentation, Lenexa KS) was calibrated (using calibration gas) according to the manufacturer's specifications. The patients were instructed to hold a full inspiration of room air for 10 seconds and then to exhale gently through the sampling system until empty (ie, as completely as they could). The highest CO (ppm) was recorded from the instrument. (All exhaled-CO measurements were performed prior to D_{LCO} measurement.) An arterial blood gas sample was obtained and analyzed using a calibrated IL282 CO-Oximeter. Using simple linear regression, HbCO = 1.92 + (0.19 x CO [ppm]), R2 = 0.83. We applied stepwise multiple linear regression analysis, which produced the equation COHb = 2.97 + (0.20 x CO [ppm]) - (1.68 x % predicted D_{LCO}), r^2 = 0.87. TLC, FEV_1, FEV_1/FVC, and combined hemoglobin saturation (HbO2 + HbCO) did not contribute significantly ($p > 0.05$) to the regression model. **Conclusion**: We conclude that portable CO monitors, such as the Vitalograph EC50, can be used to determine HbCO in patients, although the degree of D_{LCO} impairment affects the relationship between CO (ppm) in alveolar gas and HbCO in blood after a 10-second breath-hold. (OF-90-093)

Neonatal and Pediatric Mechanical Ventilation

High Frequency Ventilation of Rabbits with Induced Respiratory Failure—Kim Cavanagh MEd RRT, The Wichita State University; Tom Rose RRT, RA Nelson MD, Barry Bloom MD, HCA-Wesley Medical Center—*Wichita, Kansas.*

Introduction: Clinical trials during the development of the Infant Star High-Frequency Ventilator (Infrasonics Inc, San Diego CA) generally held the frequency constant at 10 Hz. Thisstudy was designed to determine if altering the frequency of high frequency ventilation (HFV), provided by the Infant Star, would affect ventilation in rabbits without lung disease. **Method**: Twenty-four New Zealand white rabbits were anesthetized and stabilized on conventional mechanical ventilation (F_{IO_2} = 1.0) and then converted to HFV. Amplitude of HFV was then held constant. Frequencies of 5, 10, 15, and 20 Hz were delivered in random order and in duplicate. Arterial blood gas samples were obtained and analyzed at each frequency after stabilization. **Results**: ABG values demonstrated that most effective ventilation (as reflected by a change in P_{aCO_2} from baseline—ie, ΔP_{aCO_2}) was at 5 Hz, followed by 15 Hz, 10 Hz, and finally 20 Hz. **Discussion**: The reason for this non-linear relationship is unclear. The existence of an optimal frequency for HFV requires further study. Fixed frequencies are beneficial in protocol development, but, in light of the observed clinically significant Δ P_{aCO_2} of 8 torr, the fixed frequency of 10 Hz used in the clinical trials during development may not represent a most-optimal-use strategy for this device.



Mean (SD) of P_{aO_2}, ΔP_{aCO_2}, and $\bar{P}_{aw}$ at varying frequencies. Values for ΔP_{aCO_2} at 5 vs 10 vs 20 Hz are statistically significant, $p < 0.05$ (ANOVA and Kruskal-Wallis). (OF-90-004)

Pressure-Volume Parameters as They Relate to Ventilatory Strategy in the Premature Baboon—Dale R Gerstmann, Joseph M Guerra, Matt Guajardo, Robert A deLemos, Southwest Foundation for Biomedical Research, *San Antonio, Texas.*

We sought to compare several different ventilatory strategies in a premature baboon model of hyaline membrane disease (HMD). **Methods & Materials**: We examined pressure-volume (P-V) loops on excised lungs of 124 premature baboons delivered at 80% of gestation (140 d) and supported in an NICU for 24 hours. There were four treatment groups: conventional ventilation (CV) (n = 60), surfactant and CV (CV + SURF) (n = 28), high-frequency oscillatory ventilation (HFOV) (n = 24), and CV with HFOV rescue (CV + HFOV) (n = 12). All animals received appropriate O_2. We measured percentage of lung water (% H_2O), degree of hysteresis (ie, P-V curve area [PVarea]), deflation stability (ie, pulmonary stability index [PSI]), residual volume (RV), volume after deflation (V_0), inflatability as maximum volume (V_{max}) and inflation volume (V_I), and static compliance (C_L = V_I/pressure at

V_{max}). The BEAR Cub (Bear Medical, Riverside CA), Healthdyne 100 (Healthdyne Technologies, Marietta GA), Sechrist Neonatal (Sechrist Industries, Anaheim CA), and Infant Star (Infrasonics, San Diego CA) ventilators were used to provide CV; the SensorMedics High-Frequency 3200 and 3100 ventilators (SensorMedics, Yorba Linda CA) were used to provide HFOV. Surfactant (natural or artificial) was administered (100 mg/kg) immediately after intubation in the CV + SURF treatment group. **Results:**

Comparative Effects of Different Ventilatory Strategies on P-V Loop Data

	CV	CV + SURF	HFOV	CV + HFOV
% H_2O	0.76 (0.02)	0.81 (0.02)	0.79 (0.03)	0.69 (0.03)*
PVarea	29 (5)	55 (6)	71 (8	34 (10)*
PSI	0.74 (0.07)	0.57 (0.09)	0.43 (0.11)	0.64 (0.14)
RV	1.7 (0.4)	2.5 (0.5)	2.9 (0.7)	1.6 (0.8)
V_0	2.1 (0.5)	3.3 (0.6)	3.4 (0.8)	2.6 (1.0)
V_{max}	4.1 (0.6)	7.2 (0.8)	10.9 (1.1)	4.7 (1.4)†
V_I	2.3 (0.4)	4.7 (0.5)	6.0 (0.6)	3.1 (0.8)†
C_L	0.09 (0.01)	0.15 (0.02)	0.25 (0.02)	0.11 (0.03)†

All values are mean (SE); units for volume are mL/g dry lung weight; units for compliance are (mL/g)/cm H_2O.
* $p < 0.05$, ANOVA.
† $p < 0.001$, ANOVA.

Discussion: These data suggest that HFOV treatment during HMD in this premature baboon model provided a high level of early alveolar volume recruitment, independent of volume stability contributed by administered surfactant. Higher C_L with HFOV appears to be a function of greater V_{max}, implying that lungs receiving HFOV inflate as easily without surfactant as do lungs that have received added surfactant. **Conclusion:** The findings of this study suggest that in HMD the poor mechanical properties exhibited by the lungs in response to CV may be due to factors other than just the absence of surfactant. (OF-90-092)

Effect of Flow, Inspiratory Time, and Ventilator Brand on Lung Overdistention—Robert M Lewis BA RRT. The Children's Memorial Hospital, *Chicago, Illinois.*

Lung overdistention may occur in respiratory distress syndrome (RDS) during treatment with mechanical ventilation, especially as lung compliance improves. Reduction of inspiratory time (T_I) and flow ($\dot{V}$) has been recommended to reduce lung overdistention. We compared the effects of T_I, $\dot{V}$, and ventilator brand on lung overdistention using a lung model. **Methods:** A Bio-Tek VT-2 lung simulator (Bio-Tek Instruments Inc, Winooski VT) set at C = 1 mL/cm H_2O (to simulate an infant with RDS), was ventilated with the Infant Star (Infrasonics, San Diego CA), BP 200 (Bear Medical, Riverside CA), BEAR Cub (Bear Medical), Servo 900C (Siemens Life Support, Schaumburg IL), Sechrist (set for sine wave) (Sechrist Industries, Anaheim CA), and Sechrist (set for square wave) (Sechrist Industries, Anaheim CA). Ventilator settings were: Setting 1—PIP 30 cm H_2O, $\dot{V}$ 20 L/min, T_I 0.66 s, f 30/min, PEEP 0.0 cm H_2O; Setting 2—PIP 30 cm H_2O, $\dot{V}$ 20 L/min, T_I 0.17 s, f 120/min, PEEP 0.0 cm H_2O; Setting 3—PIP 30 cm H_2O, $\dot{V}$ at minimum required to maintain PIP of 30 cm H_2O, T_I 0.66 s, f 30/min, PEEP 0.0 cm H_2O; Setting 4—PIP 30 cm H_2O, $\dot{V}$ at minimum required to maintain PIP of 30 cm H_2O, T_I 0.17 s, f 120/min, PEEP 0.0 cm H_2O. As each ventilator was adjusted to each of the 4 groups of settings, the compliance (C) of the Bio-Tek VT-2 was set at 1 mL/cm H_2O (to simulate an infant with RDS), and tidal volume (V_T) and maximum lung volume (V_{max} = V_T + end-expiratory volume [EEV]) were measured; then C was increased to 3 L/cm H_2O (to simulate a recovering infant), and V_T and V_{max} were measured again. Each trial was repeated three times. **Results:**

Variable Settings	Maximum Lung Volume (V_{max})* Ventilators					
	Infant Star	BP 200	BEAR Cub	Servo 900C	Sechrist (sine wave)	Sechrist (square wave)
1 (high $\dot{V}$, high T_I)	87	86	93	82	81	90
2 (high $\dot{V}$, low T_I)	47	50	43	36	60	42
3 (low $\dot{V}$, high T_I)	36	50	38	36	45	39
4 (low $\dot{V}$, low T_I)	39	39	41	33	59	36

*V_{max} is in mL, and was measured with lung simulator C set at 3 L/cm H_2O.

All ventilators produced the highest V_{max} at Setting 1 (high $\dot{V}$ and high T_I). Lowest V_{max} was always produced with low $\dot{V}$: Setting 3 for BEAR Cub, Infant Star, and Sechrist (sine wave); and Setting 4 for Servo 900C, BP 200, and Sechrist (square wave). V_{max} increased as C was increased from 1 to 3 L/cm H_2O, by an amount that varied with ventilator brand and settings (from 210% with the BEAR Cub at Setting 1 to 13% with the Servo 900C at Setting 4). V_{max} increases were generally due to increases in V_T. Only the BP 200 and Sechrist (sine wave) produced an EEV > 6 mL at C = 3 L/cm H_2O (at Settings 1, 3, and 4). Likewise, at C = 1 L/cm H_2O, V_T changed by more than 10% for only the BP 200 and Sechrist (sine wave) due to increasing $\dot{V}$ and/or decreasing T_I. Analysis of variance showed that ventilator brand has a significant effect ($p < 0.05$) on V_{max} increases as C increases. **Conclusions:** This lung-model study suggests that lung overdistention, during recovery from RDS, can be minimized by reduction of $\dot{V}$ and/or T_I. These reductions had little effect on V_T for most ventilators tested in this study. The ideal ventilatory pattern varies with ventilator brand. (OF-90-084)

Effects of Lung Compliance, Airway Resistance, and Endotracheal-Tube Size on Volumes Delivered by a High Frequency Oscillator—F Herbert Douce MS RPFT RRT, The Ohio State University, *Columbus, Ohio*; James Castillo BS, Cleveland Clinic Foundation, *Cleveland, Ohio*; Larry Sachs PhD, The Ohio State University, *Columbus, Ohio.*

Although high-frequency oscillatory ventilation (HFOV) has been approved by the Food and Drug Administration for the treatment of pulmonary interstitial emphysema (PIE) in infants, little is known about the volumes delivered in this mode of ventilation under different clinical conditions. The purpose of this study was to determine how volume delivered to a lung model is affected by changes in endotracheal-tube (ET) size, airways resistance, and lung compliance during HFOV. **Meth-**

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ods: We used an infant lung simulator (DB & M Products, Redlands CA) that provides three levels of lung compliance (C_L) (1, 3, and 10 mL/cm H_2O) and three levels of airway resistance (R_{aw}) (20 cm $H_2O \cdot s \cdot L^{-1}$ at $\dot{V}_I$ of 30 L/min, 50 cm $H_2O \cdot s \cdot L^{-1}$ at $\dot{V}_I$ of 15 L/min, and 200 cm $H_2O \cdot s \cdot L^{-1}$ at $\dot{V}_I$ of 3 L/min). We determined the actual lung compliances of the simulator by directly injecting 10 known volumes of air with a 50-mL graduated syringe and observing the lung pressure change with each injection. We connected a strip-chart recorder (Model #9811, American Edwards Labs, Irvine CA) to the 10 mV/cm H_2O output of the lung simulator, and adjusted the gain to assure that 1 cm H_2O equaled 1 mm over the range of 0 to 50. We set an Infant Star ventilator (Infrasonics, San Diego CA) in the HFOV mode at V_I 8 L/min, PEEP 10 cm H_2O, and f 15 Hz; we connected the ventilator to the lung model and maintained the amplitude between 48 and 52. We randomly selected one of four ET sizes (2.5, 3.0, 3.5, and 4.0 mm ID), three lung compliances, and three airway resistances; and repeated observations seven times with each combination. We recorded the changes in lung pressure and calculated volume delivered to the lung by multiplying the actual lung compliance by the change in lung pressure. We computed mean volume delivered for each combination and compared means with ANOVA and Covariance with repeated measures and Tukey's HSD post hoc comparison; we defined significant differences as $p < 0.05$. **Results**: The delivered volumes ranged from 0.20 mL to 16.8 mL. Significantly different volumes were delivered for each ET size and R_{aw}. Significantly higher volumes were delivered when $C_L$was set at 10 L/cm H_2O, compared to C_L of 1 and 3 L/cm H_2O. ET size and R_{aw}, C_L and ET size, and C_L and R_{aw} interacted significantly. **Conclusion**: The findings of our lung model study demonstrate that varying the combinations of ET size, R_{aw}, and C_L does affect volumes delivered by HFOV with an Infrasonics Infant Star ventilator. (OF-90-088)

Flow-Synchronized Ventilation of Very-Low Birthweight Infants: Preliminary Evaluation of a New Device—Gina Servant BS RRT, Steven Donn MD, Cheryl Lathrop BS RRT, Joanne Nicks RRT, Kenneth Bandy RRT. University of Michigan Medical Center, *Ann Arbor, Michigan.*

Prior attempts to assist spontaneously breathing preterm infants receiving mechanical ventilation have been limited by the inability of the infants to generate adequate negative pressure. The Ventilator Flow Synchronizer (Bird Products Corp, Palm Springs CA) was developed to synchronize spontaneous breathing to ventilator cycling by responding to changes in gas flow at the proximal airway. In this study we sought to evaluate the efficacy of flow-synchronized ventilation (FSV), using this device, in preterm infants. **Methods**: Included in our study were seven preterm infants with RDS (birthweight 610-1,240 g, gestational age 25-31 wk), who were receiving conventional mechanical ventilation (CMV): intermittent mandatory ventilation (IMV) via a Sechrist IV-100B conventional, time-cycled, pressure-limited ventilator (Sechrist Industries Inc, Anaheim CA). Each infant was monitored for 1 hour during conventional mechanical ventilation alone (CMV1), 1 hour during CMV and FSV in combination (CMV + FSV), and 1 hour during CMV alone again (CMV2). During each study period, arterial blood pressure, heart rate, respiratory rate, inspiratory time, mean airway pressure, and pulse-oximetry oxygen saturation were continuously monitored. Pulmonary mechanics and arterial blood gases were measured at the end of each study period. Data were analyzed using repeated measures analysis of variance. For those measured parameters in whom means varied between study periods, pairwise comparisons were computed with an experiment-wise alpha error built in. **Results**: Respiratory rate (mean [SD]) during CMV + FSV (47.7 [14.7] breaths/min) was significantly higher than during either CMV1 (26.9 [6.1] breaths/min) or CMV2 (26.6 [6.0] breaths/min) ($p = 0.01$). Arterial oxygen tension (mean [SD]) during CMV + FSV (87.1 [12.6] torr) was significantly higher than during CMV1 (66.1 [8.1] torr) ($p = 0.04$). No adverse effects were observed in any study subjects. **Discussion**: During FSV, the increase in mechanical respiratory rate (related to increased patient triggering) may have been responsible for the significant increase in oxygenation that was observed and for an increase (although not significant) in P_{aw} that was also observed. **Conclusions**: These preliminary results suggest that FSV can be provided safely to even the smallest of preterm infants. Further long-term evaluation of FSV in controlled clinical trials is indicated. (OF-90-108)

Rescue Use of a High-Frequency Flow Interruptor for Neonatal Pulmonary Air Leak—Kelvin MacDonald RCP, Ralph E Franceschini MD, Bikramjit Sangha MD, David Wirtschafter MD. Kaiser Permanente Medical Center, *Los Angeles, California.*

Pulmonary air leak resulting from mechanical ventilation significantly increases neonatal morbidity and mortality. We conducted a 'rescue' trial using a high-frequency flow interrupter (HFFI), prior to its approval for sale by the Food & Drug Administration (FDA) for the treatment of neonatal pulmonary air leak. **Methods**: Patients were eligible for entry into our study if they met the following criteria: $\bar{P}_{aw} > 8$ cm H_2O, $P_{aCO_2} > 50$ torr with an $F_{IO_2} \geq 0.8$, radiographic evidence of air leak, and failure of conventional ventilation. Informed consent was obtained for all patients. Eight patients were enrolled in the trial. Mean (SD) birthweight was 1296 (410) g. Mean (SD) $\bar{P}_{aw}$ prior to HFFI was 11.6 (2.8) cm H_2O, mean (SD) PIP was 33 (3) cm H_2O, mean (SD) F_{IO_2} was 0.99 (0.04), and mean (SD) P_{aCO_2} was 77 (13) torr. Two patients had chest tubes in place. An Infant Star ventilator (Infrasonics, San Diego CA), equipped with the HFFI module, was used. The frequency was fixed at 15 Hz with a minimum IMV rate of 4 breaths/min. **Results**: Twelve hours after initiation of HFFI, the mean (SD) $\bar{P}_{aw}$ was 9.8 (2.5) cm H_2O, mean (SD) P_{aCO_2} was 50 (12) torr, and mean F_{IO_2} was 1.0. Mean time on HFFI was 36 hours, with radiographic resolution of air leak in 24-48 hours. No changes in cardiovascular status were associated with HFFI. Using a multivariate analysis method described by Gaylord et al (Pediatrics 1985;76:219-224), we determined that the rescue group had a predicted pulmonary mortality of approximately 50%. No pulmonary related fatalities occurred, although one patient was returned to conventional ventilation without incident after the di-

agnosis of necrotizing enterocolitis was made. **Conclusion**: The ability to lower P_{aCO_2} and $\bar{P}_{aw}$, through use of the HFFI, appears to have improved outcome in this small group of patients. (OF-90-052)

Aerosolized Antibiotic Delivery Is Ineffective when Used with Continuous-Flow Ventilation—Elba Fayard MD, Wesley R Brown CRTT, Gerald Nystrom MD. Loma Linda University Medical Center, *Loma Linda, California.*

Gram-negative pneumonia is a major source of morbidity and mortality in the newborn infant. Aerosolized aminoglycosides have been used for the treatment of pneumonia in adults and older children, but very little is known about their use in newborns. In a previous study of intubated newborns with pseudomonas pneumonia, we compared patient response to aerosol and intravenous aminoglycoside in combination to intravenous therapy alone. We saw no significant difference in clinical response or in the blood levels of the medication. **Research Question**: What amount of gentamicin is delivered to the lungs by aerosolization technique? **Method**: 10 New Zealand rabbits (1.2 to 2.4 kg) underwent tracheotomy, were paralyzed, and mechanically ventilated with continuous-flow ventilation. Gentamicin (30 mg/kg) diluted in saline (4 mL) was aerosolized using an Aerotech 2 aerosol generator (Cadema, Middletown NY) (mass median aerodynamic diameter of 1 micron). The aerosol generator was placed in-line 15 cm from the patient Y-connector. Within 1 min after completion of aerosolization, a blood gentamicin level was obtained. The animal was then sacrificed, and lung lavage was performed. Ventilator inspiratory tubing was rinsed with saline. Gentamicin levels were obtained from lung lavage, ventilator tubing rinse, and aerosol-generator residual volume. **Results**: Because of continuous-flow ventilation, drug delivery to the patient is limited to inspiratory time only. This factor allowed for only 13.6% of the initial drug mass to be delivered during the inspiratory time.

Amount of Gentamicin Recovered from Various Sites

	Aerosol Generator	Tubing	Lung Lavage	Blood
Mean% recovered	40.3	5.7	0.5	0.7
Range% recovered	(24.0 - 72.4)	(0.5 - 10.1)	(0.2 - 1.3)	(0.0 - 2.7)

Conclusions: Our findings suggest that aerosolizing gentamicin through a continuous flow ventilator-circuit system allows a very small amount of medication to reach the lung. If aerosolization is to be used to administer antibiotics to infants, more investigation must be done to determine the initial amount of drug needed to deliver an effective dose to the lungs. (OF-90-144)

Long-Term Mechanical Ventilation and Long-Term Care

Evaluation of an Interdisciplinary Approach to the Rehabilitation of the Ventilator-Dependent Patient: A Case Study—Daniel W Dubowski RRT, Kathy Ellis MSN CRRN, Thomas Klaus MD. Lake Erie Institute of Rehabilitation, *Erie, Pennsylvania.*

Case Summary: An 85-year-old woman was injured (no seat belt) in a MVA on 5-19-89. She was found unconscious at the scene, with a non-union fracture at the base of the odontoid process and posterior subluxation of C-1 through C-2 (required wiring and bone graft). CT scan of the head revealed areas of hemorrhage. Resultant effects of closed head injury (CHI) included impaired arousal, attention, and cognition, and the obvious inability to perform activities of daily living (ADLs). At the time of discharge from acute care, she was a ventilator-dependent quadriplegic. Past medical history was significant for acute MI (x 2), and subsequent CABG approximately 6 weeks preceding her injury. Consulting pulmonologists had predicted poor prognosis for weaning and return of cognition. On admission to Lake Erie Institute of Rehabilitation on 6-29-89, she exhibited only slight motor activity in the left upper and left lower extremities. Atrophy of her right extremities was progressive. Spontaneous tidal volumes were 300-400 mL at a rate of 20-25 breaths/min. Admission ventilator settings were IMV at 10/min, F_{IO_2} 0.30, V_T 700 mL. Interventions established by the interdisciplinary team were: (1) suctioning and trach care each shift and PRN (patient was weaned slowly by T-piece); (2) daily speech/cognitive-therapy sessions addressing orientation and increasing voice volume through deep-breathing exercises and cueing to taking deep breaths prior to speaking; (3) OT twice per day to increase use of the right upper extremity—an ADL program was utilized to teach adaptive dressing and bathing techniques and the use of assistive devices, and a resting pan splint as well as paraffin treatments were utilized to improve range of motion (ROM) of the right hand; (4) PT focused on ROM and facilitation techniques, and wheelchair mobility training and, eventually, ambulation training were undertaken as endurance improved; (5) the patient progressed first to a pureed and then to a regular diet. The patient (1) was weaned from ventilator on 8-27-89 and decannulated on 9-29-89; (2) became a functional verbal communicator, 100% audible, with good pragmatic skills; (3) became independent in ADLs including laundry and meal preparation; (4) became ambulatory, with supervision needed only for ascending and descending stairs; and (5) ate a regular diet for all meals. The patient was discharged to own apartment after 138 days (4 1/2 months). No follow-up outpatient therapies were required other than homemaker assistance, for safety reasons only. **Conclusion**: Implementation of a true interdisciplinary plan of care produces positive outcomes. RCPs need to become involved with all aspects of rehabilitation. The need for rehabilitation services and alternate sources of care will increase in the future (Goldberg AI. Respir Care 1990;35:247-259). Interdisciplinary care planning for ventilator-dependent patients holds promise for worthwhile results. (OF-90-114)

Quality Respiratory Care of Chronic Ventilator Patients: Perceptions of Patients vs Practitioners—Crystal L Dunlevy EdD RRT, Ruth E Sagula CRTT. The Ohio State University, *Columbus, Ohio.*

Chronic ventilator patients comprise a unique population of respiratory care recipients. They have generally been exposed

to a number of respiratory care procedures and practitioners, and as a result they have become fairly familiar with both. These patients may also experience isolation, frustration, fear, and confusion as a direct result of their ventilator dependence. These emotions may be minimized by respiratory care practitioners (RCPs) who recognize and understand them. The purpose of this study was to compare perceptions of quality respiratory care from both the patient's and the RCP's viewpoints. **Methods**: One hundred RCPs from central Ohio were randomly selected from the Ohio Society for Respiratory Care membership list and asked to complete a 55-item questionnaire consisting of items related to their perceptions of quality respiratory care as well as their perceptions of patient opinions regarding quality respiratory care. Sixty-five RCPs (65%) responded to the survey. Questions were divided into subgroups of communication, psychological and emotional, physical, and miscellaneous factors. Sixteen patients who had been ventilator dependent for a minimum of 2 months were interviewed, using items parallel to those on the RCP questionnaire. Both instruments required responses to be ranked on a Likert-type scale. Means and standard deviations were calculated for each item. Two-tailed *t* tests were applied to each set of responses, with $p < 0.05$ considered to be statistically significant. **Results**: According to item-by-item analysis, 69% of the responses of the patients and RCPs differed enough to be considered statistically significant. Further, 50% of the item responses dealing with communication, 70% of those addressing psychological components, 92% of the items concerning physical aspects of ventilator care, and 100% of the miscellaneous items were found to differ significantly between patients and RCPs. **Conclusions**: It is apparent from the data analysis that RCPs are often unaware of patients' feelings and attitudes with respect to the care they receive. By creating awareness among RCPs of these patient attitudes, the quality of patient care may be improved and the ventilator-dependent patient's anxieties allayed. (OF-90-115)

A Gas-Conservative Method for Manually Providing Continuous-Flow IMV during Recreational Transport—Charles Kettell AS RRT. Maine Medical Center, *Portland, Maine.*

A gas-conservative method for manually providing continuous-flow IMV was developed at my institution to facilitate taking chronic IMV-dependent patients out of the ICU for recreational purposes. **Description of Method**: The method utilizes a setup consisting of a Downs adjustable flow generator (#9250, Vital Signs, Totowa NJ), two Instrumentation Industries exhalation valves (#BE115, Instrumentation Industries, Bethel Park PA), a Bird one-eighth-inch tubing T (#358, Bird Products, Palm Springs CA), a Bird one-way valve (#5537, Bird Products, Palm Springs CA), and other parts commonly used in respiratory care. The Downs generator provides flow, and the resuscitator one-way valve and exhalation valves allow a manual breath to be delivered from a location distant to the patient. Prior to patient use, the circuit is assembled and appropriate patient flow (≥ 20 L/min) and F_{IO_2} are set. The circuit is attached to the patient's artificial airway with a heat-and-moisture exchanger in-line, and the tubing is brought over the patient's shoulders and secured. The tank is secured on the wheelchair, with the resuscitator well behind the patient. The patient breathes spontaneously through the circuit until the resuscitator is squeezed—at which point the circuit closes, the flow generator is isolated, and the patient receives a manual breath. During transport, the therapist pushing the wheelchair is able to deliver the manual breaths to the patient. **Experience**: This new IMV method has been successfully used on an infant, a young child, and a 65-year-old adult for many in-hospital trips, two trips home, and a trip to the local golf course. (The golf trip lasted 2.5 hours and required two full E cylinders of oxygen.) The highest rate that has been used is 12 breaths/min and the highest F_{IO_2} used has been 0.60; PEEP has not been used. All transports using this new method have been trouble-free. **Conclusion**: Experience at my institution suggests that this is a safe gas-conservative method for manually providing continuous-flow IMV during recreational transport. However, a controlled study with a larger number of subjects will be necessary to confirm the safety and efficacy of this new method. (OF-90-095)

Summer Camp for Ventilator-Dependent Children, in a Natural Setting Away from Primary Care Providers—Mary K Dekeon RRT, Robert T Remenapp RN, Huda Rosen RRT, Dietrich W Roloff, MD. University of Michigan, *Ann Arbor, Michigan.*

Approximately 2,000 U.S. children have been discharged from hospital to home on mechanical ventilation. The amount of care required to maintain a child on mechanical ventilation in the home, and the associated financial burden and emotional stress imposed on the child, family, and community are only beginning to be felt. As health care providers we understand that these stresses can be devastating to the family. We designed a 5-day/5-night summer camp to provide: (1) a 'camp' experience for ventilator-dependent children focusing on abilities rather than disabilities, encouraging independence, and allowing the children to develop friendships with others having similar handicaps; (2) respite for the children's families, during which time the parents can be assured that their children are receiving quality care and are having an enjoyable experience; and (3) an opportunity for the medical staff to donate their specialized training and to have positive experiences with these children in a camp environment. Eighteen ventilator-dependent children were enrolled in the program (age range 28 months to 23 years, median age 6.6 years; ventilator dependence range 7 months to 17 years, median 3.2 years.) The staff-to-camper ratio was 48:18, with the following breakdown:

Makeup of the Staff

n	Title	Responsibility	Credentials
18	Partners	An individual child	RRT or RN
10	Cabin leaders	Supervise cabin activity	RRT or RN
10	Health team	Administer medications and treatments	2 MDs, 2 RRTs, and 6 RNS
8	Activity staff	Plan and implement activities	2 OTs, 1 PT, 1 Rehab Engineer, 1 Speech Pathologist, 1 teacher, and 2 students
2	Administrators	Coordinate all phases	1 RRT and 1 RN

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The financial burden of such a camp can be exorbitant; however, all staff members donated their time. Other camp costs totalled $11,000. A grant for $7,000 was received and the remaining money was obtained through various fund-raising events. Camp was provided free of charge to all families. Campers, parents, and staff agreed that the experience was more rewarding than expected. **Conclusion**: This pilot project demonstrates that a camp for ventilator-dependent children can be beneficial to those participating in the camp as well as to parents and siblings who do not attend. (OF-90-157)

Case Summary: The Use of Pressure Support in Weaning a C-4 Quadriplegic Patient from Mechanical Ventilation—Paula Burke Brockenbrough BS CRTT, H David Reines MD. Donald Marion MD. Medical College of Virginia Hospital, *Richmond, Virginia.*

A 24-year-old man was admitted to our Trauma Emergency Room after sustaining a gunshot wound to the neck. He presented with a C-4 flaccid quadriplegia and agonal respirations. Admission arterial blood analysis, with the patient on a 100% nonrebreathing mask, revealed pH 7.03, P_{CO_2} 79 torr, and P_{O_2} 130 torr. MRI of the cervical spine showed a comminuted fracture of the C-4 vertebral body with retropulsed fragments causing moderate cord compression He was placed on an Emerson IMV ventilator to maintain a P_{CO_2} of 35-45 torr. No spontaneous breathing was noted above the set IMV rate. After 2 days on standard IMV, he was placed on the Puritan-Bennett 7200a ventilator with pressure support ventilation (PSV). This was done to take advantage of his minimal respiratory effort, as evidenced by volume and pressure measurements (see Table). PSV was set to achieve a 5-7 mL/kg tidal volume. The patient was weaned to CPAP/PSV in 2 days. Fluoroscopy at 11 days showed a paralyzed right diaphragm; therefore, low-rate IMV was used in conjunction with PSV to prevent collapse. PSV was used to exercise the ventilatory muscles, thus helping to keep the diaphragm in condition but not allowing it to fatigue. At 29 days the patient had an anterior cervical corpectomy of C-4. At 38 days the patient was on CPAP/PSV continuously. Fluoroscopy at 44 days showed return of right diaphragmatic function. The level of PSV was slowly decreased while maintaining a spontaneous tidal volume of 5-7 mL/kg. At 55 days, the patient was placed on continuous tracheostomy collar.

Volume and Pressure Measurements*

Time (post injury)	MIP	MEP	V_T	VC
12 h	-2 cm H_2O	+2 cm H_2O	< 50 mL	-----
4 d	-8 cm H_2O	+6 cm H_2O	60 mL	150 mL
44 d	-12 cm H_2O	+8 cm H_2O	130 mL	350 mL
55 d	-20 cm H_2O	+18 cm H_2O	400 mL	750 mL

*MIP = maximal inspiratory pressure; MEP = maximal expiratory pressure; V_T = tidal volume; VC = vital capacity.

Conclusion: Our experience suggests that there may be a role for PSV in the weaning of quadriplegic patients from mechanical ventilation, because PSV allows patients to exercise ventilatory muscles, conditioning them for endurance. Randomized studies involving quadriplegic patients are needed to further determine the usefulness of PSV as a weaning tool for this population. (OF-90-076)

Comparison of Respiratory-Muscle Training Methods in Spinal-Cord-Injury Patients—Daniel C DeGroot RRT. University of Wisconsin Hospital & Clinics, *Madison, Wisconsin.*

In our study we sought to compare the effectiveness of two different methods of respiratory muscle training in spinal-cord-injury patients. **Method & Materials**: During a 1.5-y period, all C3-C7 spinal-cord-injury patients at our institution for whom respiratory muscle training was prescribed were entered into our study. Patients were assigned on an alternating basis to use one of three training methods: Method A consisted of using a fixed-orifice respiratory-muscle training device (made at our hospital) that incorporates a 3-mm inspiratory port to create resistance to flow; Method B consisted of using a threshold-loading respiratory-muscle training device (Threshold, HealthScan Products Inc, Cedar Grove NJ); Method C consisted of performing diaphragmatic breathing exercises. All subjects were seen on a BID frequency 5 days/week for 8 weeks, and FVC, FEV_1/FVC, PEFR, and MIP were measured initially, once per week during the study, and at the conclusion of 8 weeks of training. Method-A subjects trained for 15 min/session at 33% of their most recently measured MIP; Method-B subjects trained for 5 min/session at 50% of their most recently measured MIP; Method-C subjects performed diaphragmatic breathing exercises for 15 min/session. (Training intensity was adjusted on a weekly basis for subjects using Methods A and B) Subjects who missed > 10% of their scheduled therapies or who demonstrated poor compliance with the therapy were dropped from the study. A total of 15 subjects completed 8 weeks of training with one of the three methods: A (n = 6), B (n = 6), and C (n = 3). **Results**: No statistically significant differences ($p < 0.05$) between methods were observed in the degree of improvement in expiratory parameters. However, statistically significant improvements in MIP were observed when Methods A ($p < 0.05$) and B ($p < 0.01$) were compared to Method C.

Comparison of 8-Week Improvement in Respiratory Parameters between Methods of Training

	Method A	Method B	Method C
FVC	15.8 (1.1)*	37.5 (12.0)	16.4 (7.6)
FEV_1/FVC	6.3 (7.2)	5.3 (3.1)	3.3 (3.3)
PEFR	38.0 (11.4)	45.5 (8.0)	24.3 (13.5)
MIP	73.1 (12.0)	100.0 (6.0)	38.4 (2.0)

* All respiratory parameters are reported as mean (± SEM) % increases.

Conclusion: Our findings suggest that in spinal-cord-injury patients both fixed-orifice and threshold-loading methods of respiratory muscle training result in increased inspiratory muscle strength, and that less therapist-patient time may be required per training session if training is performed at a higher intensity (ie, %MIP). (OF-90-015)

Fatal Mucus-Ball Obstruction of the Central Airway in a Transtracheal Oxygen Therapy Patient—George Burton MD, Fred A Wagshul M, Wesley Kime MD, Diannah Henderson RN. Kettering Medical Center, *Kettering, Ohio.*

Few serious and no fatal complications of transtracheal oxygen therapy (TTO_2T) have yet been reported in the literature. Increased mucus production has been reported in the first 2-4 weeks following placement of TTO_2T catheters, but no predominate cough or sputum production has been evident in the majority of patients. We report a case of fatal obstruction of the trachea by a 7.0 x 3.0 x 3.0 cm mucus ball around a TTO_2T catheter. **Case Summary**: A 50-year-old male smoker with COPD and pulmonary fibrosis was hospitalized for cough and severe dyspnea 3 weeks after placement of a TTO_2T catheter by a physician specially trained in the procedure. The patient had experienced only minor episodes of mucus-ball expectoration prior to admission. The patient demonstrated pulmonary hyperexpansion and diminished bilateral breath sounds. No localized findings (such as pneumonia or atelectasis) were found on physical examination or on serial chest radiographs. He demonstrated progessive respiratory insufficiency, but per his request he was not intubated. Throughout his hospital course, he complained of "suffocation." The patient had been extremely compliant with all respiratory care modalities, before and during his final admission. The patient expired of respiratory failure on the fourteenth hospital day. At autopsy, a mucus ball was found to completely fill the tracheal lumen. It was tightly adherent to the tracheal wall and extended from the tip of the TTO_2T catheter to the bifurcation. Histologic examination showed irritation and necrosis of the tracheal wall. Moderate pulmonary fibrosis and COPD were present as well. **Conclusion**: Because of the nonspecificity of physical findings associated with mucus ball obstruction of the trachea, we suggest that serial flow-volume loop analyses and/or fiberoptic bronchoscopy be performed in TTO_2T patients who are experiencing post-procedure cough and otherwise unexplained dyspnea. In this manner, perhaps early diagnosis of this potentially fatal complication of TTO_2T can be made. (OF-90-002)

Nocturnal Oximetry in Re-Evaluation of Long-Term Oxygen Therapy—Vijay Chechani MD, Gary Scott MEd RRT. Harry S Truman Memorial Veteran's Hospital, *Columbia, Missouri.*

Introduction: Patients with chronic obstructive pulmonary disease (COPD) and daytime, resting (room air) arterial oxygen tension (P_{aO_2}) ≥ 60 torr or oxygen saturation ≥ 90% are not eligible for long-term oxygen therapy (LTOT) by Health Care Financing Administration (HCFA) criteria. Re-evaluation of continued need for LTOT in 41 COPD patients (1-5 y after initiation of LTOT) revealed 13 patients with daytime, resting (room air) P_{aO_2} between 60-69 torr. All of these patients firmly believed that they needed supplemental oxygen, and 6 of the patients also had symptomatic coronary artery disease. Sustained nocturnal hypoxemic episodes (≥ 1 min) can cause clinically important myocardial dysfunction; thus, these 13 patients were further evaluated for desaturation, by pulse oximetry, during exercise and sleep. **Methods**: Oxygen saturation determined by pulse oximeter (S_{pO_2}) was continuously monitored while each of the 13 patients (breathing room air) performed a 12-min walk test and slept for 3 hours at night. Clinically important desaturation was considered to be a drop in S_{pO_2} to ≤ 88% during walking or to ≤ 85% for ≥ 1 min during sleep. Lowest S_{pO_2} during sleep, longest nocturnal desaturation episode (≤ 85%), and total amount of sleep time spent with S_{aO_2} ≤ 85% were compared to severity of COPD, exercise desaturation, and daytime, resting (room air) blood gas tensions. **Results**: Clinically important desaturation was observed in 10 patients (4 during the walk test and 9 during sleep). Desaturation in these patients could be corrected with low-flow supplemental oxygen via nasal cannula, and their LTOT prescriptions were modified accordingly. LTOT was discontinued in the 3 patients who did not exhibit desaturation during walking and sleep. Severity of COPD, exercise desaturation, and daytime, resting (room air) blood gas tensions did not prove to be useful predictors of nocturnal desaturation. **Conclusions**: Our findings suggest that the need for LTOT should not be determined solely on the basis of daytime (room air) resting or exercise P_{aO_2} or S_{pO_2} values; nocturnal oxygen desaturation must also be considered. Nocturnal pulse-oximetry monitoring appears to be a useful means to identify those patients for whom LTOT is needed to prevent nocturnal hypoxemia. (OF-90-110)

Determining the Need for and Prescribing Home Oxygen: Is Spot-Check Oximetry and ABG Analysis Enough?—Mary Coyle BSN RN, WN Donovan MD, JW Sehloff MD, Steve M Dalebroux RRT, Jim Dorsey RRT. St Mary's Hospital Medical Center, *Madison, Wisconsin.*

It has been shown that oxygen therapy increases the longevity and quality of life in patients with chronic hypoxemia. The purpose of this study was to assess whether oxygen desaturation in the home environment can be predicted with baseline spot-check measurement of oxygenation and pulmonary function. **Method**: Sixteen patients (mean age 69 y) with stable COPD were studied. Baseline ABG, PFT (including D_{LCO}), and pulse-oximeter-determined oxygen saturation (S_{pO_2}) values were obtained. ABG and S_{pO_2} measurements were performed simultaneously. None of the subjects met the Medicare established criteria (P_{aO_2} ≤ 55 torr, S_{aO_2} ≤ 88%) for oxygen reimbursement. The subjects were then continuously monitored by oximetry (Nonin, 8604-D) at home: S_{pO_2} was recorded every min for 18 h (12 PM to 6 AM) on 2 separate days, 1 wk apart, for a total of 36 h. We discarded S_{pO_2} values that represented a greater than ± 5% change in 1 min and those values that were identified (with an asterisk) by the oximeter as being potentially artifactual. **Results**: Desaturation (defined as drop in S_{pO_2} to ≤ 88%) occurred in all of the patients an average of 19% of the time. Baseline spot-check oximetry and ABG-analysis did not predict the likelihood of desaturation. We found no correlation between any PFT abnormality and degree

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of desaturation. When subjects were divided into two activity groups (inactive vs moderately active), we found no statistically significant difference in mean 36-h S_{pO_2} between groups ($p > 0.05$, $t = 0.29$). **Conclusions:** We conclude that baseline spot-check S_{pO_2}, ABG, and PFT measurements will not reliably predict which patients are likely to desaturate. Therefore, in patients who on the basis of baseline spot-check assessment of oxygenation meet the Medicare-established criteria for oxygen reimbursement, we recommend use of continuous oximetry studies to ensure adequacy of the oxygen prescription; in patients with compromised respiratory status who on the basis of baseline spot-check assessment of oxygenation fail to meet Medicare criteria, we recommend use of continuous oximetry studies to determine whether prescription of supplemental oxygen may nevertheless be indicated. (OF-90-011)

Editor's Note:

The Call for Abstracts for the 1991 Open Forum will be available at the Convention in New Orleans. In addition, it will be published in the Journal from January through May 1991. We encourage you to plan ahead for the 1991 RESPIRATORY CARE Open Forum.

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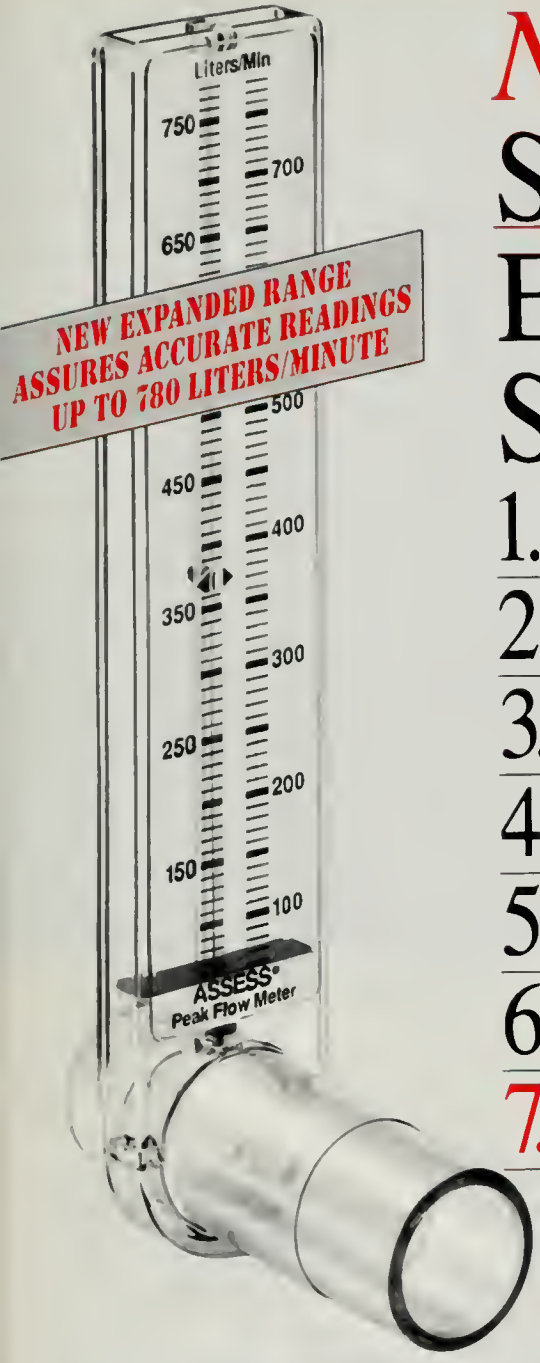

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References 1. Hendler J, Shapiro S, Ogirala R, Aldrich T. Accuracy of new and used portable peak flow meters. Abstract presented at the 46th Annual Meeting of the American College of Allergy and Immunology, Orlando, FL, November 11-15, 1989. 2. Shim CS, Williams MH. Relationship of wheezing to the severity of obstruction in asthma. *Arch Intern Med 143* 890, 1983. 3. Williams MH. Expiratory flow rates: Their role in asthma therapy. *Hospital Practice* 95, October, 1982. 4. Woolcock AJ, Yan K, Salome CM. Effect of therapy on bronchial hyperresponsiveness in the long-term management of asthma. *Clinical Allergy 18* 165, 1988.

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December 8-11, 1990
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Saturday, December 8	12 Noon - 4:00 PM
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Monday, December 10	11:00 AM - 4:00 PM
Tuesday, December 11	11:00 AM - 3:00 PM

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December 8-11 in New Orleans, Louisiana. The AARC presents its 36th Annual Convention and Exhibition at the New Orleans Convention Center. Contact the AARC, 11030 Ables Ln, Dallas TX 75229. (214) 243-2272.

December 15 in Miami, Florida. The Florida Society for Respiratory Care presents "The Legal Aspects of Medical Litigation," including a formal mock medical malpractice trial, at the Miami Airport Hilton Hotel. Speakers and role-players are all practicing attorneys and/or legal specialists. The due process includes full litigation from deposition to trial. Contact Dave Robbins at (305) 441-6819.

February 19-22 in Reno, Nevada. The American Lung Association of Nevada and the Nevada Society for Respiratory Care present the 10th Annual High Sierra Critical Care Conference at the Peppermill Hotel Casino. This four-day conference presents critical care topics covering adult, pediatric, and neonatal issues. Contact Barbara Rothstein, American Lung Association of Nevada, PO Box 7056, Reno NV 89510. (702) 825-5864 (9AM-3PM PST).

February 21-22 in Kansas City, Missouri. The Kansas and Missouri Respiratory Care Societies, in conjunction with the Respiratory Care Managers Association (KS/MO), sponsor the 3rd Annual Midwest Respiratory Care Symposium at Baptist Medical Center, 6601 Rockhill Rd, Kansas City MO 64131. Contact Clarissa Craig, Program Director, Respiratory Therapy Education, Johnson County Community College, 12345 College at Quivira, Overland Park KS 66210-1299. (913) 469-8500, ext 3939.

OTHER MEETINGS

January 13-18 in Miami, Florida. A 6-day/5-night "Cruise for Pulmonary Patients and Friends" departs from the port of Miami to Key West and Mexico, leaving on Sunday and returning on Friday. Group rates include private stateroom (double occupancy required) and all on-board meals and entertainment. Special airfare rates are available upon request. Deadline is December 17. Contact Dave Robbins at (305) 441-6819.

February 10-13 in Sun Valley, Idaho. St Helena Hospital of Deer Park, California, and the American College of Chest Physicians (ACCP) cosponsor a program on "Cardiopulmonary Wellness and Rehabilitation." Contact Darlene Buczak at the ACCP, (708) 698-2200.

April 14-21 Mexican Riviera Cruise. "Each One, Teach One" is the theme for this year's spring cruise for 8 education units (CEU). Cruise only $775 for prepaid, double occupancy. Call (800) 462-3628; or write Dream Cruises, 10882 La Dona Ave, Garden Grove CA 92640.

AARC ANNUAL CONVENTION SITES & DATES

1990—New Orleans, Louisiana, December 8-11
1991—Atlanta, Georgia, December 7-10
1992—San Antonio, Texas, December 12-15
1993—Nashville, Tennessee, December 11-14
1994—Las Vegas, Nevada, December 12-15
1995—Orlando, Florida, December 2-5

RESPIRATORY CARE

Instructions for Authors and Typists

These Instructions are meant to guide authors and typists, including veterans in those roles, in the production of quality manuscripts. Perfection is not expected, but the well-prepared manuscript has the best chance for prompt review and early publication.

General Requirements

Submissions should (1) be related to respiratory care, (2) be planned for one of the publication categories below, and (3) be prepared as indicated in these Instructions. A letter accompanying the manuscript must specify the intended publication category, be signed by all the authors, and, when there are two or more authors, state that "We, the undersigned, have all participated in the work reported, read the accompanying manuscript, and approved its submission for publication."

Publication Categories

Research Article (Study): A report of an original investigation.
Evaluation of a Device/Method/Technique: A description and evaluation of an old or new device, method, technique, or modification.
Case Report: A report of a clinical case that is uncommon or of exceptional teaching value. The author(s) must have been associated with the case. A case-managing physician must be one of the authors or, if not an author, must supply a letter approving the manuscript.
Case Series: Like a Case Report but including a number of cases.
Review Article: A comprehensive, critical review of the literature and state of the art of a pertinent topic that has been the subject of 40 or more published research papers.
Overview: A critical review of a pertinent topic about which not enough research has been published to merit a Review Article.
Update: A report of subsequent developments in a topic that has been critically reviewed (not necessarily in this journal).
Point of View: A paper expressing the author's personal opinions on a pertinent topic.
Special Article: If a paper does not fit one of the foregoing categories but is pertinent, the editors may consider it as a Special Article.
Editorial: A paper that draws attention to a pertinent concern.
Letter: A signed communication about material published in this journal or on topics of interest or value to readers.
Blood Gas Corner: A brief, instructive case report (real or fictional) involving invasively or noninvasively obtained respiratory care blood data, followed by questions for readers—with answers and discussion.
PFT Corner: Like Blood Gas Corner but involving pulmonary function testing.
Test Your Radiologic Skill: Like Blood Gas Corner and PFT Corner but involving pulmonary-medicine radiography and including one or two 4 × 5 or 5 × 7 inch prints of radiographs. The case must be real.
Review of Book, Film, Tape, or Software: Anyone interested in writing a review can discuss it with an editor.

Editorial Consultation and Author's & Typist's Kit

To discuss a writing project, write to RESPIRATORY CARE, 11030 Ables Lane, Dallas TX 75229 or call 214/243-2272.

Authors are urged to obtain the RESPIRATORY CARE Author's & Typist's Kit. The Kit provides *authors* with specific guidance about writing a research paper, writing a case report, converting to and from SI units, and in-house manuscript review. *Typists* can use the Kit's Model Manuscript, a list of journal name abbreviations, and a copy of these Instructions. The Kit is free from the Journal office.

Preparing the Manuscript

General Concerns—*Typist*

- Double-space ALL lines, including those in references, figure legends, and tables. Do not justify right margins.
- Number pages in upper right corner and leave margins of 1½" or more on all four sides of the page.
- For research articles, follow format of Model Manuscript, Respir Care 1984;29:182 (Feb 1984).
- Meticulously follow instructions for typing references.

General Concerns—*Author:*

- Structure manuscript as specified hereafter.
- Provide all requested information on title page as specified hereafter.
- Proofread manuscript for completeness, clarity, grammar, spelling; be sure all references, figures, and tables are cited in the text.
- Consider having paper reviewed in-house before submission.
- Have all co-authors proofread and approve manuscript and sign submission letter.

Manuscript Structure

Most kinds of papers have standard parts in a standard order. However, papers can vary individually, and not every paper will have all the parts listed here.

Research Article: Title page, abstract page, continuous text (Introduction, Materials & Methods, Results, Discussion), Product Sources page, Acknowledgments page, references, tables, figure legends. Please consult "Writing a Research Paper," Respir Care 1985;30:1057 (Dec 1985) and Model Manuscript, Respir Care 1984;29:182 (Feb 1984).
Evaluation of Device/Method/Technique: Title page, abstract page, continuous text (Introduction, Description of Device/Method/Technique, Methods of Evaluation, Results of Evaluation, Discussion), Product Sources page, Acknowledgments page, references, tables, figure legends.
Case Report or Case Series: Title page, abstract page, continuous text (Introduction, Case Summary, Discussion), Acknowledgments page, references, tables, figure legends. Also see "How To Write a Better Case Report," Respir Care 1982;27:29 (Jan 1982).
Review Article: Title page, Table of Contents page, continuous text (Introduction, History, Review of Literature, State of the Art, Discussion, Summary), references. May include figures & tables. No abstract. Table of Contents optional. Other formats may be appropriate.
Overview, Update, Point of View, or Special Article: Title page, text (introduction, message), references, tables, figure legends. No abstract.
Letter: Title page (provide a title), text, writer's name & affiliation, references. Tables & figures may be included. Double-space everything. Write "For Publication" on title page.

Structure: Important Details

Title Page: List title of paper, all authors' full names, degrees, credential letters, professional positions, and affiliations. List correspondence address, telephone number, and reprint address if desired. Name sources of grants or other support. Identify any author's consulting or commercial relationships that pertain to the paper's topic.

Abstract Page: Number this Page 1. List paper's title but omit authors' names. Abstract should be 200 words or less and must be informative, briefly specifying main points of paper, such as methods, results, and conclusions drawn.

Statistical Analysis: In research articles, identify statistical tests and chosen level of significance in the Methods section. In Results section, report actual P values.

Figures (illustrations): All photographs, diagrams, & graphs must be numbered as Figure 1, Figure 2, etc, according to the order in which each is first mentioned in the text. Photographs must be glossy prints 5 × 7 to 8 × 10 inches and should be black & white unless color is essential. Letters and numerals must be neat and large enough to remain legible if figure is reduced in size for publication. Final figures must be of professional quality, but 'rough' sketches may accompany the submitted manuscript, with final figures to be prepared after review. Identify each figure on back with a stick-on label showing figure number and arrow indicating top; omit author's name. Cover label with clear tape so ink will not smudge other prints. Supply three sets of unmounted figures. If figure has been published before, include copyright-holder's written permission to use it.

Figure Legends: List figure legends on a separate page, not on figures. If a figure has been published before, list the source in the legend.

Tables: Type each table on a separate page. Avoid more than 8 columns across. Continue a deep table on following pages. Give each table a number and descriptive title, placed above the table. Double-space ALL lines in tables, including column headings and footnotes.

Drugs: Brand names may be given, but always also show generic names.

Units of Measurement: In addition to conventional units of measure, show SI values and units in brackets after conventional expressions: ie, "PEEP, 10 cm H_2O [0.981 kPa]." For conversion to SI, see RESPIRATORY CARE 1988;33:861-873 (Oct 1988).

Commercial Products: If three or fewer commercial products are named in the text, list the manufacturer's name and location in parentheses the first time each is mentioned. If four or more products are named, do not list manufacturers in the text; instead, name the products and manufacturers in a Products Sources list at the end of the text. Provide model numbers when available.

Abbreviations: Use an abbreviation only if the term occurs several times in the paper. Write out the full term the first time it appears, followed by the abbreviation in parentheses. Thereafter, employ the abbreviation alone. Never use an abbreviation without defining it. Do not create new abbreviations unless absolutely necessary.

References:

- Use references to support statements of fact, indicate sources of information, or guide readers to further pertinent literature.
- Cite only published works—or works accepted for publication. When listing an accepted but still unpublished work, designate the accepting journal's name, followed by "(in press)."
- In the text, cite references by superscript numerals (half space above text), not in parentheses. The first reference cited in the text is number 1, the next is number 2, etc.
- In the reference list, place the cited works in numerical order.
- For the reference list, obtain author names, article and book titles, dates, volume and page numbers from the *original* cited articles and books, not from secondary sources such as other articles' reference lists, which often are inaccurate.
- Type references in medical-journal style. Examples appear at the end of these Instructions. Abbreviate journal names as in *Index Medicus*. A list of many journal-name abbreviations was published in Respir Care 1988;33:1050 (Nov 1988).
- DOUBLE-SPACE the lines of references.
- List ALL authors' names. Do not use "et al" to substitute for names.
- Identify abstracts, editorials, and letters as such. See examples.

Personal Communications, Unpublished Papers, and Unpublished Observations: List unpublished items in parentheses in the text, not in the reference list.

Examples of How To Type References

Notes: Although the examples here are printed with single-spaced lines, please double-space references in manuscripts. Also, note that words in article and book titles are not capitalized—except proper names.

Standard Journal Article:

1. Shepherd KE, Johnson DC. Bronchodilator testing: An analysis of paradoxical responses. Respir Care 1988;33:667-671.

Corporate Author Journal Article:

2. American Association for Respiratory Care. Criteria for establishing units for chronic ventilator-dependent patients in hospitals. Respir Care 1988;33:1044-1046.

Article in Journal Supplement:

(Journals differ in their methods of numbering and identifying supplements. Supply sufficient information to allow retrieval.)

3. Reynolds HY. Idiopathic interstitial pulmonary fibrosis. Chest 1986;89(3, suppl):139s-143s.

Abstract in Journal:

(Abstracts are not strong references; when possible, full papers should be cited. When cited, abstracts should be identified as such.)

4. Lippard DL, Myers TF, Kahn SE. Accuracy of pulse oximetry in severely hypoxic infants (abstract). Respir Care 1988;33:886.

Editorial in Journal:

5. Rochester DF. Does respiratory muscle rest relieve fatigue or incipent fatigue? (editorial). Am Rev Respir Dis 1988;138:516-517.

Letter in Journal:

6. Smith DE, Herd D, Gazzard BG. Reversible bronchoconstriction with nebulised pentamidine (letter). Lancet 1988;2:905.

Personal Author Book:

7. Nunn JF. Applied respiratory physiology. New York: Appleton-Century-Crofts, 1969.

Note: To specify pages cited in a book, place a colon after the year and then list the page(s). Examples: 1969:85 (one page), 1963:85-95 (series of contiguous pages), 1963:85,95 (separated pages).

Corporate Author Book:

8. American Medical Association Department of Drugs. AMA drug evaluations, 3rd ed. Littleton CO: Publishing Sciences Group, 1977.

Book with Editor, Compiler, or Chairman as 'Author':

9. Guenter CA, Welch MH, eds. Pulmonary medicine. Philadelphia: JB Lippincott, 1977.

Chapter in Book:

10. Pierce AK. Acute respiratory failure. In: Guenter CA, Welch MH, eds. Pulmonary medicine. Philadelphia: JB Lippincott, 1977:171-223.

Submitting the Manuscript

After preparing the manuscript according to these Instructions, perform a final proofreading and check for accuracy and completeness. Then mail three copies of the manuscript and three sets of figures to RESPIRATORY CARE, 11030 Ables Lane, Dallas TX 75229 (or Federal Express to RESPIRATORY CARE, 11030 Ables Lane, Dallas TX 75229). Manuscript copy on IBM-compatible or Macintosh disks in addition to the requisite three hard copies will facilitate processing (Macintosh preferred). Enclose a letter as specified under **General Requirements** at the beginning of these Instructions. Do not submit material that has been published or is being considered elsewhere.

Author's Checklist

1. Is paper for a listed publication category?
2. Does cover letter meet specifications?
3. Is title page complete?
4. Are all pages double-spaced and numbered?
5. Are all references, figures, and tables cited in the text?
6. Are references typed in requested style?
7. Have SI values been provided?
8. Has all arithmetic been checked?
9. Has manuscript been proofread by all authors?

News releases about new products and services will be considered for publication in this section. There is no charge for these listings. Send descriptive release and glossy black and white photographs to RESPIRATORY CARE Journal, New Products and Services Dept, 11030 Ables Lane, Dallas TX 75229.

New Products & Services

COMPRESSED-GAS SAFETY TAPE. The new 42-minute VHS video tape entitled "Safe Handling of Compressed Cylinder Gases" depicts the safe handling and proper storage of compressed gas (inert, flammable, oxidizing, corrosive, poisonous, and cryogenic) in cylinders. Scott Specialty Gases Inc, Dept RC, 6141 Easton Rd, Plumsteadville PA 18949. (800) 331-4953, in Pennsylvania call (215) 766-8861.

PORTABLE VOLUME VENTILATOR. The new Companion 2801 portable volume ventilator, which replaces the Companion 2800, has been designed with expanded capabilities to meet the respiratory needs of a wider range of patients, both adult and child. According to the manufacturer the Companion 2801 features: higher operating pressure, supplemental oxygen that can be used with all modes of ventilation, built-in internal- and external-battery charging capability, a dual-function electronic meter to indicate airway pressure and battery charge levels, slide rails to permit the use of the Cascade-1a Humidifier and Bennett tubing-support arms on either side of the ventilator, and modular design that facilitates factory and customer repair. Puritan Bennett, Dept RC, 10800 Pflumm Rd, Lenexa KS 66215. (913) 469-5400 or (800) 248-0890.

DECONTAMINATION SYSTEM. The Sharps Disposal System is designed to assist medical personnel in the safe decontamination and disposal of medical 'sharps' (syringes, scalpels, razor blades, and other objects with sharp edges or points—whether metal, glass, plastic, or other material). The Sharps Disposal System consists of two separate components—a reusable collection unit and a central processing unit. Used medical sharps are placed in a collection unit immediately after care is administered, usually in the patient's room. Once inside this unit, materials are inaccessible. When full, the collection unit is attached securely to the central processing unit located near the care area. The used sharps are automatically transferred for disposal. During an hour-long procedure, the processing unit grinds and melts all materials. At the end of the cycle, a smooth, disposable plastic 'puck' is produced. According to the manufacturer, independent studies have demonstrated that the thermal decontamination processing performed by the Sharps Disposal System renders medical sharps pathogen-free in the puck form; and volume of waste is dramatically reduced (eg, 50 syringes with a volume of one quart are reduced to a puck 4 inches in diameter and ¾ inch thick). Disposal Sciences Inc, Dept RC, 8100 S Akron St, Englewood CO 80112-3508. (800) 383-3800 or (303) 799-3838.

CARDIOPULMONARY MONITOR. The CP-100 is a multifunction patient monitor designed to display continuous digital and graphic data and trend information (1, 8, 12, and 24-h trend plots) for the following vital signs and respiratory variables: core temperature (T), heartrate (HR), respiratory rate (RR), tidal volume (V_T), minute ventilation ($\dot{V}_E$), airway pressure (P_{aw}), pleural pressure (P_{pl}), airway resistance (R_{aw}), work of breathing (WOB), respiratory time fraction (T_I/T_{TOT}), and lung compliance (C_{Ldyn}). The CP-100 is also designed to measure respiratory drive ($P_{0.1}$) and forced vital capacity (FVC). Airway pressure and flow are measured with the disposable VarFlex flow transducer, which, according to the manufacturer, is a low deadspace, minimal-resistance flow transducer that is impervious to the effects of moisture, aerosolized medications, and respiratory secretions. Pleural pressure is monitored with SmartCath (size 7-Fr) esophageal balloon catheters. BICORE Monitoring Systems Inc, Dept RC, 19 Thomas St, Irvine CA 92718. (714) 380-8649 or (800) 762-7691.

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RESPIRATORY CARE

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I. Type of Instn/Practice
1 ☐ Hosp 500 or more beds
2 ☐ Hosp 300 to 500 beds
3 ☐ Hosp 200 to 300 beds
4 ☐ Hosp 100 to 200 beds
5 ☐ Hosp 100 or less beds
6 ☐ Clinic/Group Practice
7 ☐ Independent RT Provider
8 ☐ Industry (Mfgr/Sales)

II. Department
A ☐ Respiratory Ther
B ☐ Cardiopulmonary
C ☐ Anesthesia Service
D ☐ Emergency Dept

III. Specialty
1 ☐ Clinical Practice
2 ☐ Perinatal Pediatrics
3 ☐ Critical Care
4 ☐ Clinical Research
5 ☐ Pulmonary Func Lab
6 ☐ Home Care/Rehab
7 ☐ Education
8 ☐ Management

IV. Position
A ☐ Dept Head
B ☐ Chief Therapist
C ☐ Supervisor
D ☐ Staff Technician
E ☐ Staff Therapist
F ☐ Educator
G ☐ Medical Director
H ☐ Anesthesiologist
I ☐ Other MD
J ☐ Nurse

V. Are you a member of the AARC
1 ☐ Yes
2 ☐ No

RESPIRATORY CARE

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6 ☐ Clinic/Group Practice
7 ☐ Independent RT Provider
8 ☐ Industry (Mfgr/Sales)

II. Department
A ☐ Respiratory Ther
B ☐ Cardiopulmonary
C ☐ Anesthesia Service
D ☐ Emergency Dept

III. Specialty
1 ☐ Clinical Practice
2 ☐ Perinatal Pediatrics
3 ☐ Critical Care
4 ☐ Clinical Research
5 ☐ Pulmonary Func Lab
6 ☐ Home Care/Rehab
7 ☐ Education
8 ☐ Management

IV. Position
A ☐ Dept Head
B ☐ Chief Therapist
C ☐ Supervisor
D ☐ Staff Technician
E ☐ Staff Therapist
F ☐ Educator
G ☐. Medical Director
H ☐ Anesthesiologist
I ☐ Other MD
J ☐ Nurse

V. Are you a member of the AARC
1 ☐ Yes
2 ☐ No

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Poly G is a portable apnea recording system for CPAP/post surgical followup of sleep apnea patients, recording ICU patients and neonatal testing in the hospital, the sleep lab, or the home. Computerized analysis requires **IBM**, **IBM compatible** or **CNS SleepLab Systems**.

CNS®

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(800) 843-2978, in MN (612) 944-0170

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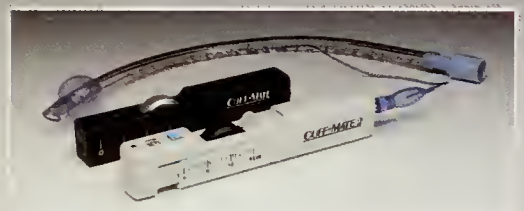
CUFF-MATE® 2

DIGITAL ENDOTRACHEAL CUFF INFLATOR AND PRESSURE MONITOR

Detail View of Cuff-Mate 2 Controls and Digital Display of Intracuff Pressure.



Choose the DHD Cuff-Mate family: Cuff-Mate (DHD 88-1105), on the left, or Cuff-Mate 2 (DHD 88-1110).

When it comes to monitoring and inflating endotracheal tube cuffs within recommended safe pressure limits[1], DHD has your number!

Cuff-Mate® 2 continues the tradition of DHDs line of durable, light-weight instruments intended for use with high volume, low pressure cuffs. Cuff-Mate 2 marries proven, state-of-the-art electronic pressure transducer and digital display technology with the features you already expect in a Cuff-Mate: calibrated volume scale and control wheel for precise, one hand operation; flashing red LED alerting the user to evaluate cuff pressures above recommended limits[1].

Digital display of intracuff pressure is highly accurate. The display on Cuff-Mate 2 is easy to read under the range of light levels found in the critical care setting. A factory installed, user serviceable battery is included with each unit. Each Cuff-Mate 2 is backed by DHD warranty against defects in materials and workmanship.

Medical literature reference bliography available from HD upon request.

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